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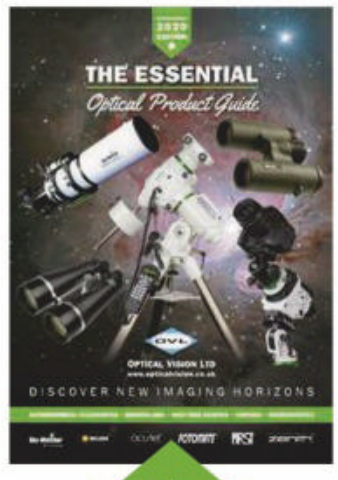

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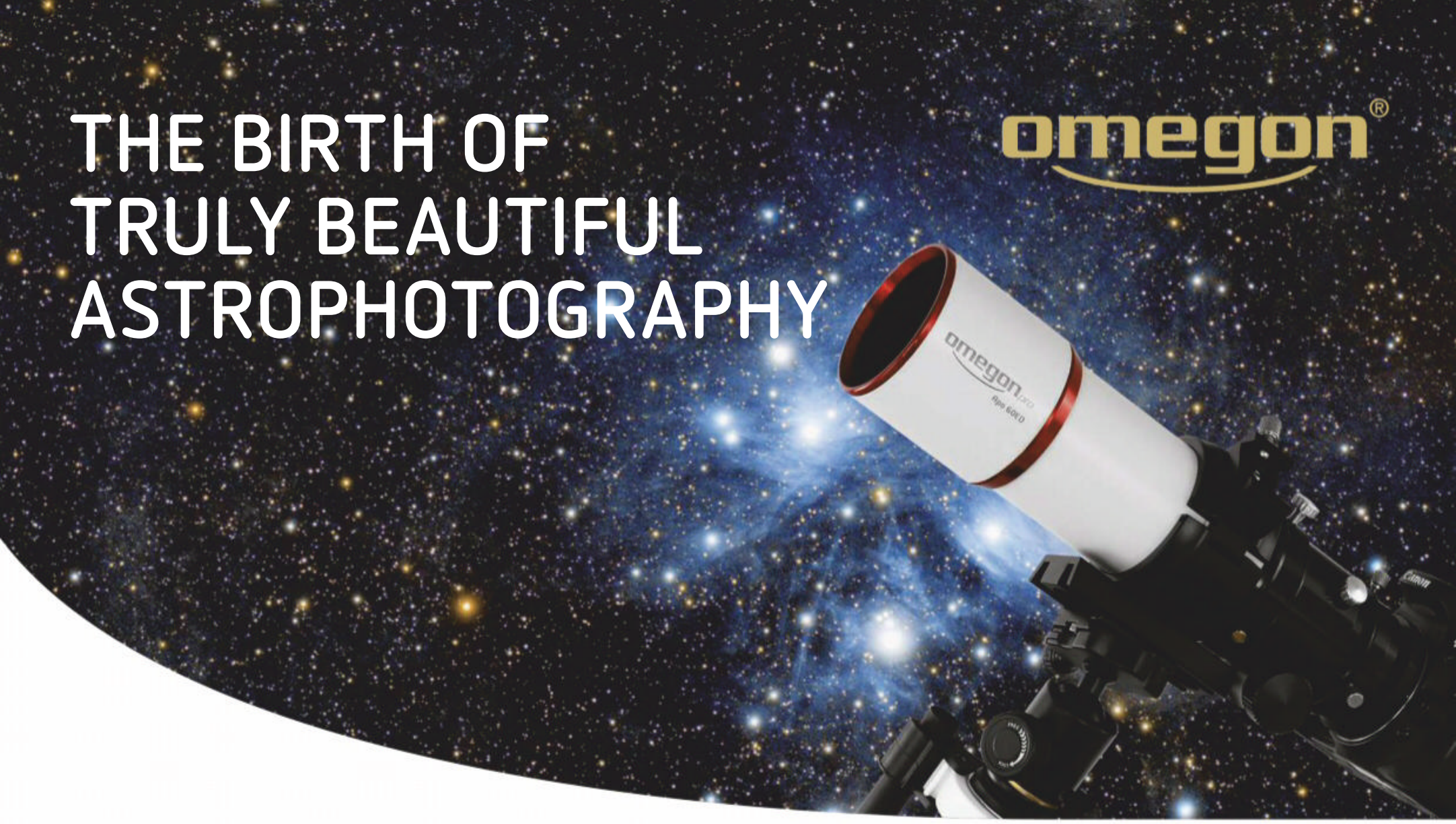

Photo: Philipp Keltenich **Taken with:** Pro APO 71/450 Quadruplet

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Pro APO 107/700 Triplet OTA					
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Welcome

We mark the 50th anniversary of the Apollo 13 mission

Early in the morning of 14 April 1970, the Apollo 13 mission was four-fifths of the way to the Moon when astronaut Jack Swigert followed a routine instruction and flicked a switch to stir the spacecraft's liquid oxygen tanks.

Fifty years on from the explosion this caused, the rescue mission that followed has lost none of its fascination, and this issue we celebrate its anniversary. On page 30 Elizabeth Pearson looks at events in the spacecraft and tells the astronauts' story, while on page 36, Rod Pyle examines events on the ground at Mission Control and how this team turned a crisis 300,000km away into a 'successful failure'. Also don't miss our interview with one of Apollo 13's Mission Control engineers on page 98. Still at NASA, he is today one of its longest-serving members.

This issue we're also starting our celebrations of another anniversary – 30 years of the Hubble Space Telescope. On page 61 Govert Schilling looks at the pivotal role Hubble played in observing the effects of dark energy. This mysterious force is one of astronomy's biggest enigmas, and currently the best theory for what's driving space to expand faster and faster. We'll be continuing our celebrations of Hubble's remarkable 30 years of observations in the next issue, which goes on sale on Thursday 23 April – the day before the anniversary of its launch on 24 April. Stay tuned!

We've got practical astronomy covered this issue too, with expert observing tips for the upcoming Lyrid meteor shower on page 66, and advice for one of this month's most alluring sights on page 46: bright Venus's path through the Pleiades star cluster – just one of the many sights to be found in our Sky Guide this month.

Enjoy the issue!

Chris Bramley, Editor

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New to astronomy?

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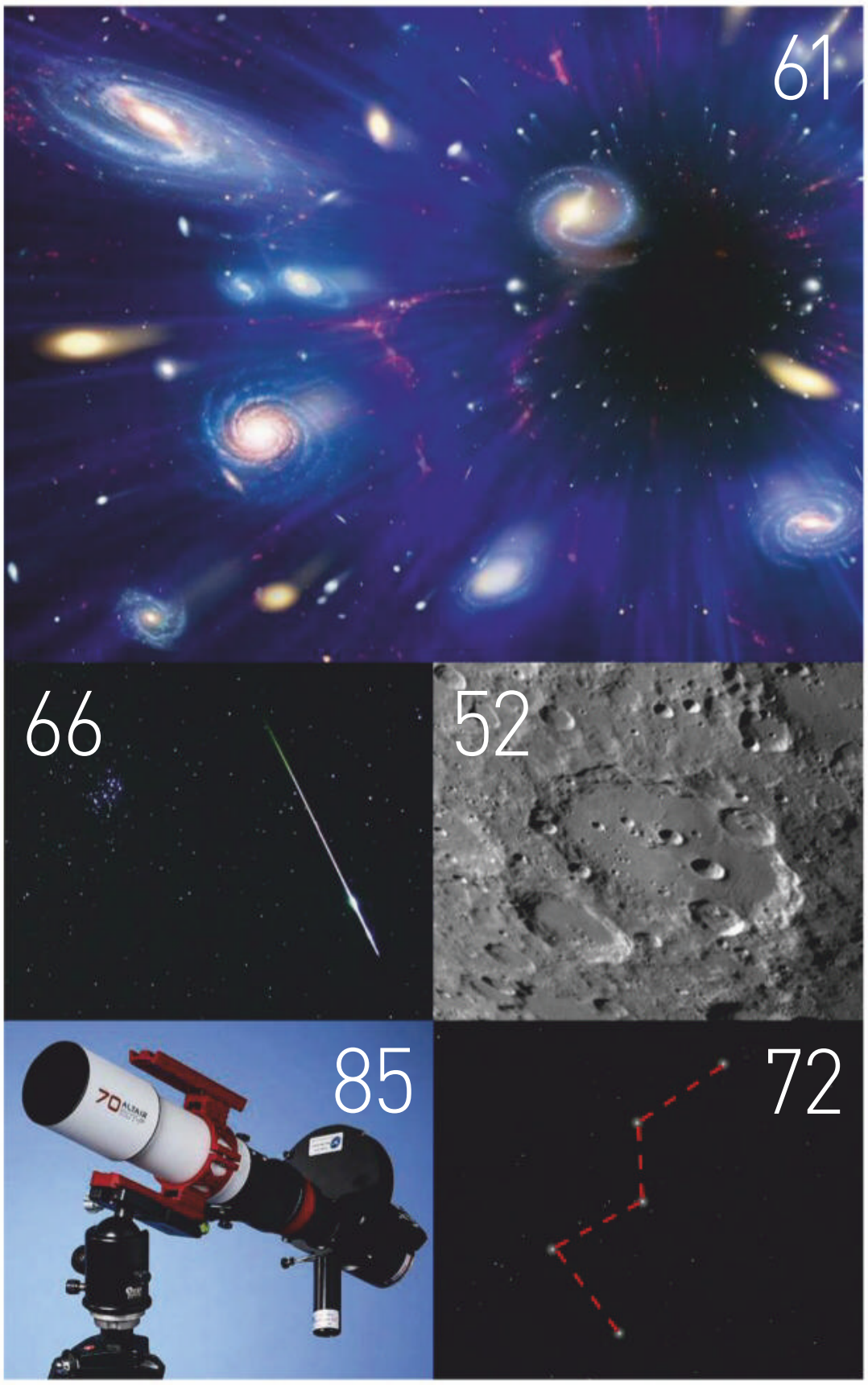
www.skyatnightmagazine.com/astronomy-for-beginners



This month's contributors

Rod Pyle

Author and journalist

"The Apollo 13 emergency could have been NASA's darkest hour, but thanks to the efforts of legions of devoted people, it became its finest. It's been thrilling to relive this bit of history!" **Rod looks at Mission Control's role in Apollo 13.** page 36

Helen O'Brien

Solar scientist

"The launch of Solar Orbiter marks a new era in the understanding of our neighbouring star. I look forward to what we can expect from this Sun explorer as it sets out on its journey of discovery". **Helen updates us about Solar Orbiter.** page 18

Scott Levine

Astronomy blogger

"I really enjoyed looking into the history of today's constellations, and giving people a way to make the sky their own by creating their own asterisms." **Scott gets to grips with the night sky's patterns.** page 72

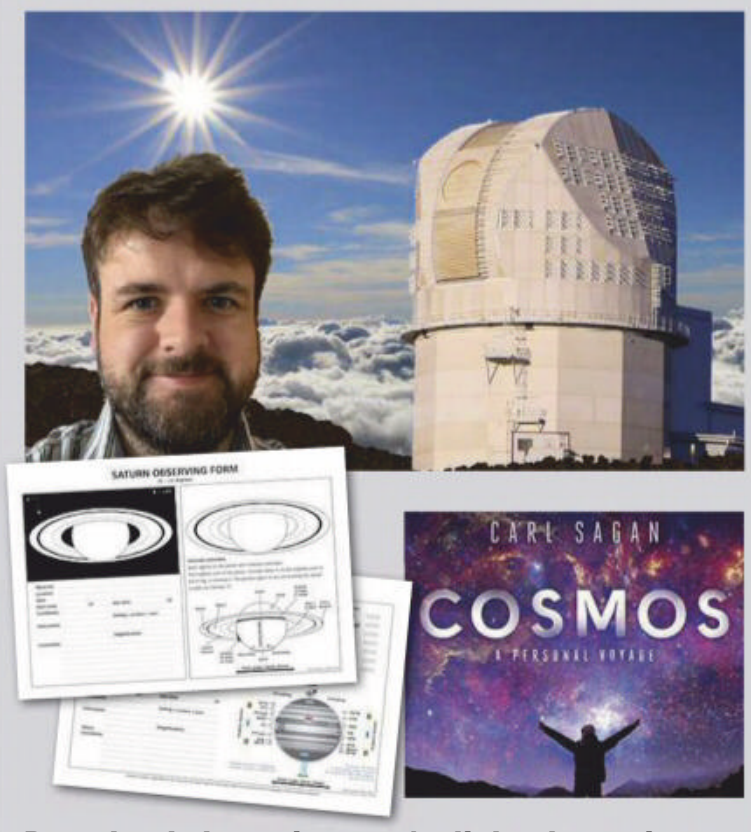
Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/D6UKHKT/** to access this month's selection of exclusive Bonus Content.

APRIL HIGHLIGHTS

A new era of solar astronomy

Solar scientist Dr Eamon Scullion reveals the latest from the most powerful solar telescope on planet Earth.



Download observing guides and charts

Access planet observing forms, binocular and deep-sky tours and our guide to southern hemisphere stargazing.

Audiobook preview: Sagan's Cosmos

Listen to two chapters from Carl Sagan's iconic work about the history of the Universe and the nature of human life.

The Virtual Planetarium

Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

Cosmic cluster COMBUSTION

Astronomers have recorded the biggest explosion ever witnessed in the Universe

CHANDRA X-RAY OBSERVATORY, XMM-NEWTON SPACE TELESCOPE, GIANT METREWAVE RADIO TELESCOPE, TWO MICRON ALL-SKY SURVEY, 27 FEBRUARY 2020

Around 390 million lightyears away a cosmic blast has occurred, generated by a supermassive black hole sitting at a galaxy's heart.

The explosion – the biggest ever recorded – was detected in one of the members of the Ophiuchus galaxy cluster. Clusters like these are the titans of the Universe, containing thousands of individual galaxies, dark matter and hot gas.

While black holes are commonly known as the vacuum cleaners of the Universe, they are also known to expel energy and cosmic material in violent outbursts. This occurs when a small proportion of infalling matter is heated and blasted into space in the form of jets.

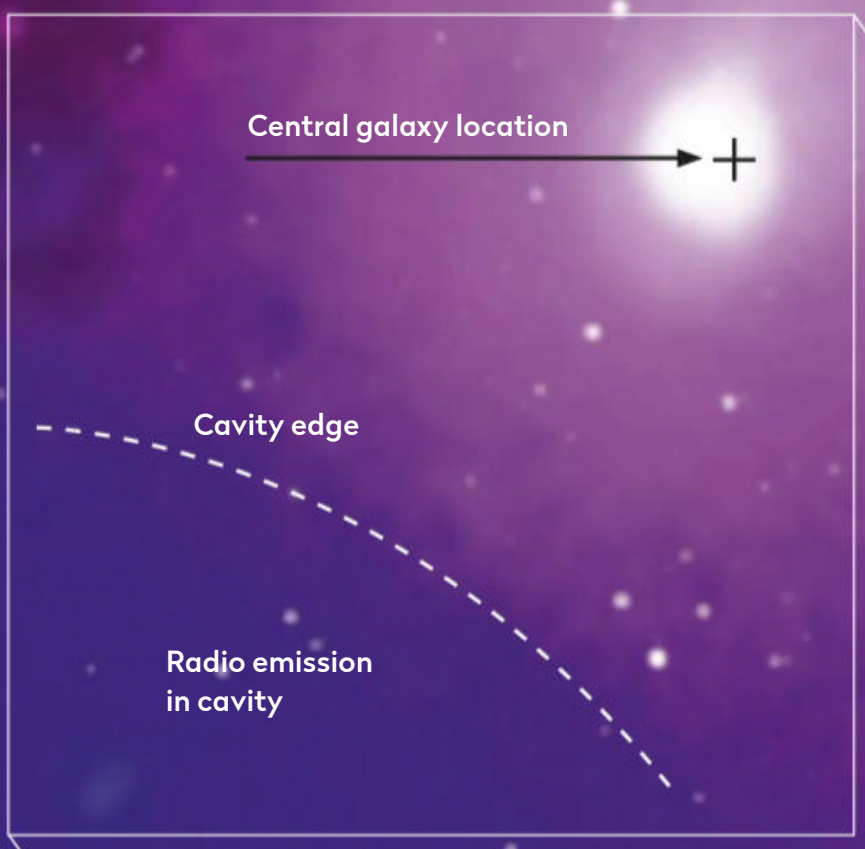
Jets have carved out a cavity in this cluster's hot gas, punching a hole that could fit 15 Milky Way galaxies aligned in a row.

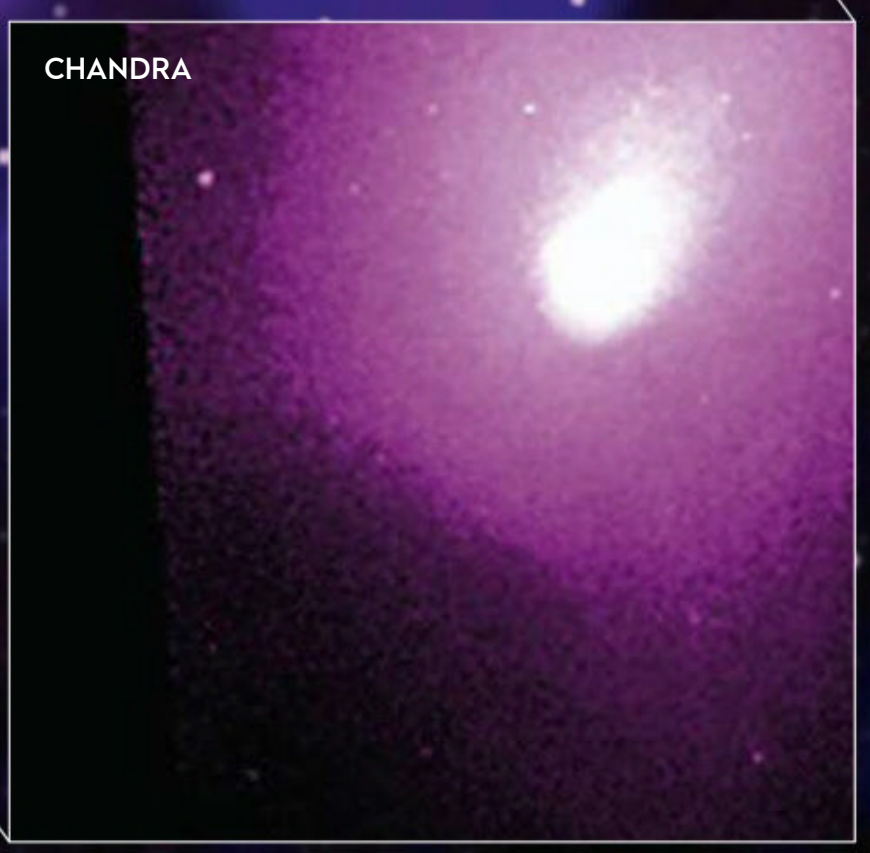
In this image, X-rays given off by the hot gas are seen in pink, radio data is blue and infrared is white. The galaxy in question is located within the white dot region surrounded by pink.

At the 7–8 o'clock position, the line between pink and blue shows the edge of the cavity, which has been filled with radio emission from electrons travelling at almost the speed of light.

X-RAY: CHANDRA: NASA/CXC/NRL/S. GIACINTUCCI, ET AL/XMM-NEWTON: ESA/XMM-NEWTON; RADIO: NCRA/TIFR/GMRT; INFRARED: 2MASS/UMASS/IPAC-CALTECH/NASA/NSF

XMM-NEWTON SPACE TELESCOPE/GIANT METREWAVE RADIO TE
TWO MICRON ALL-SKY SURVEY/CHANDRA X-RAY OBSERVATORY


Central galaxy location
Cavity edge
Radio emission
in cavity


CHANDRA

LESCOPE/

Like a circle in a spiral

HUBBLE SPACE TELESCOPE,
24 FEBRUARY 2020

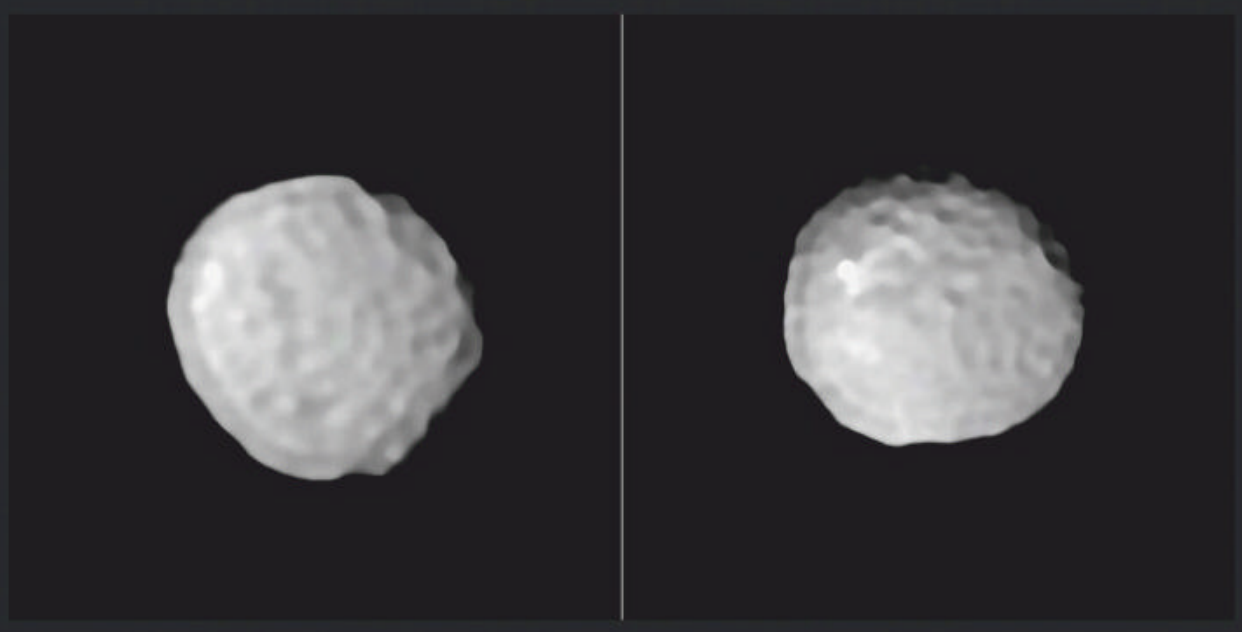
This exquisite spiral galaxy is NGC 691, 120 million lightyears away in the constellation of Aries. Discovered by British astronomer William Herschel in 1786, it was one of thousands of distant objects he was the first to catalogue. Little could he have imagined the spectacular views of far distant stars, planets and galaxies that would one day be possible thanks to the Hubble Space Telescope.

End game ▷

GEMINI OBSERVATORY, 20 FEBRUARY 2020

Beautiful in death, this is planetary nebula CVMP 1, 6,500 lightyears away in the southern constellation of Circinus, the Compass. Imaged by the Gemini South telescope on Cerro Pachón in Chile, it shows gases aglow in the radiation of a newly exposed hot core, as an old red giant star dies and casts off its outer layers into interstellar space.

MORE **ONLINE**
A gallery of these and more stunning space images



◁ Pallas uncovered

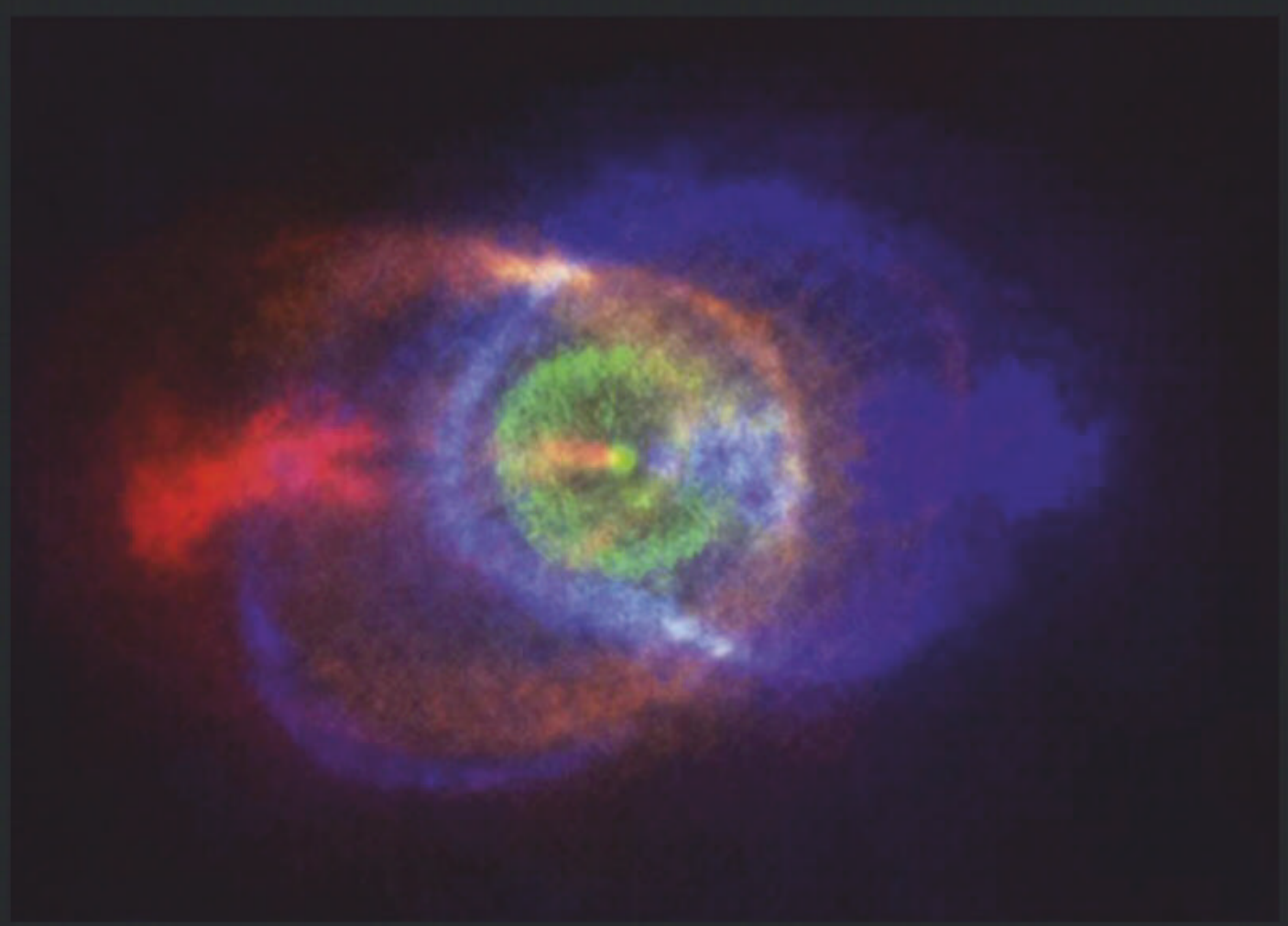
VERY LARGE TELESCOPE, 24 FEBRUARY 2020

This is the first high-resolution image to be captured of Pallas, the third largest asteroid in the Solar System. Unlike its two bigger siblings, Ceres and Vesta, it has never been visited by a spacecraft, thanks to its highly inclined orbit (almost 35° to that of Earth). So this new image of the 512km-wide asteroid, taken by ESO's Very Large Telescope, is an eye-opener, revealing a pockmarked surface suggesting a violent, collision-filled past.

Stellar showdown ▷

ATACAMA LARGE MILLIMETER/ SUBMILLIMETER ARRAY, 5 FEBRUARY 2020

These unusual kaleidoscopic gas clouds are the colourful consequence of a clash within binary system HD101584. It shows the death of a large red giant star, where a smaller companion star has spiralled into and been engulfed by it, triggering the red giant to throw off its outer gas layer. The two stars are in the single bright dot at the centre of the green ring-like structure. The blue represents gas moving the fastest towards us, while the red is gas moving the fastest away.



ESA/HUBBLE & NASA/A. RIESS ET AL, THE INTERNATIONAL GEMINI OBSERVATORY/NSF'S NATIONAL OPTICAL-INFRARED ASTRONOMY RESEARCH LABORATORY/AURA, ESO/M. MARSSET ET AL./MISTRAL ALGORITHM (ONERA/CNRS), ALMA (ESO/NAOJ/NRAO) OLOFSSON ET AL

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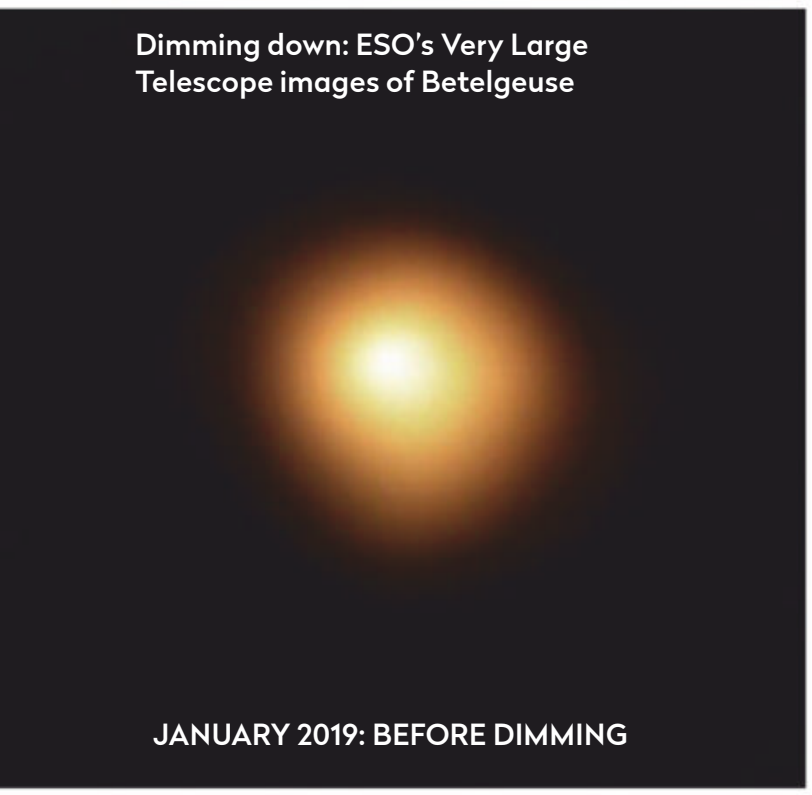
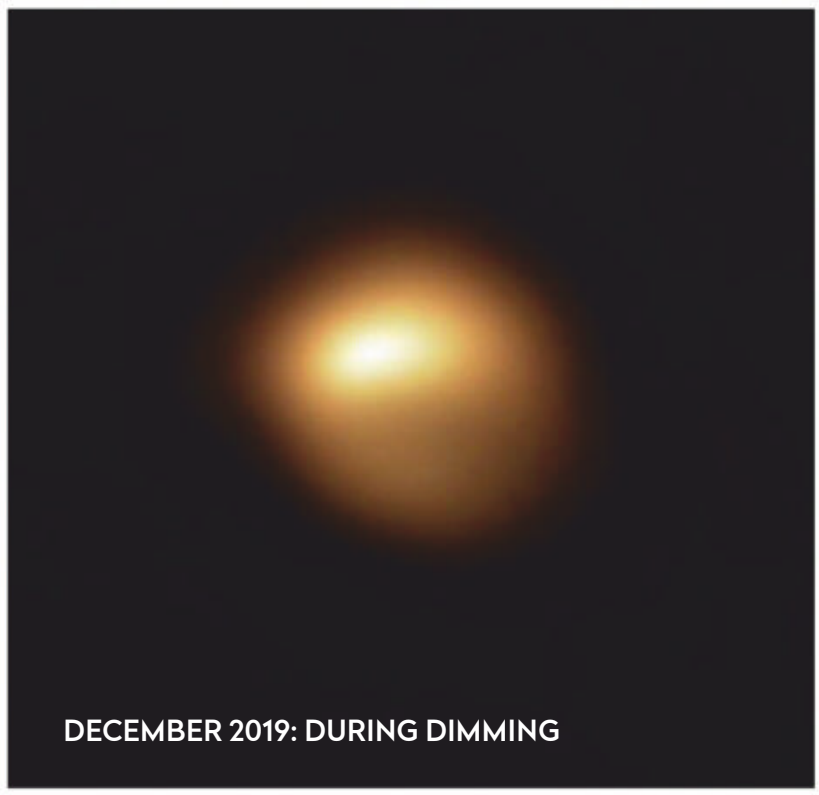


Dimming down: ESO's Very Large Telescope images of Betelgeuse



ESO/M. MONTARGÈS ET AL.

BETELGEUSE brightens up

After a faint spell, the star is getting back up to its normal brightness levels

Betelgeuse is brightening up again after a period of extreme dimming. The star reached its minimum measured brightness between 7–13 February, its magnitude dropping lower than mag. +1.6 – a third of its normal brightness. The star is a variable so its brightness does fluctuate according to a 430-day pattern, but in December 2019 the star began dipping to an unprecedented low.

As it's a red supergiant, Betelgeuse is expected to go supernova in the future. While some astronomers hoped the fainting could be a sign of imminent explosion, the star is not expected to die for another 100,000 years or so.

Instead it appears that two cycles of dimming and brightening lined up to create the unusual low. Using these patterns, astronomers from Villanova University predicted the star would bounce back within a week of the 21 February, matching up with the observed recovery.

"The star has stopped dimming and has started to slowly brighten," says Edward Guinan of Villanova University. "Thus, this 'fainting' episode is over."

Not all astronomers are as convinced. A paper by Emily Levesque from the University of Washington looked at the temperature of the star. This suggests a fundamental change to Betelgeuse. And this isn't the only evidence of a shift in the star. In December 2019, ESO's Very Large Telescope in Chile observed its surrounding dust was different to observations taken in January 2019.

"The two scenarios we are working on are a cooling of the surface due to exceptional stellar activity or dust ejection towards us," says Miguel Montargès, from KU Leuven, who conducted the observation. "Of course, our knowledge of red supergiants remains incomplete and this is still a work in progress, so a surprise can still happen."

www.eso.org

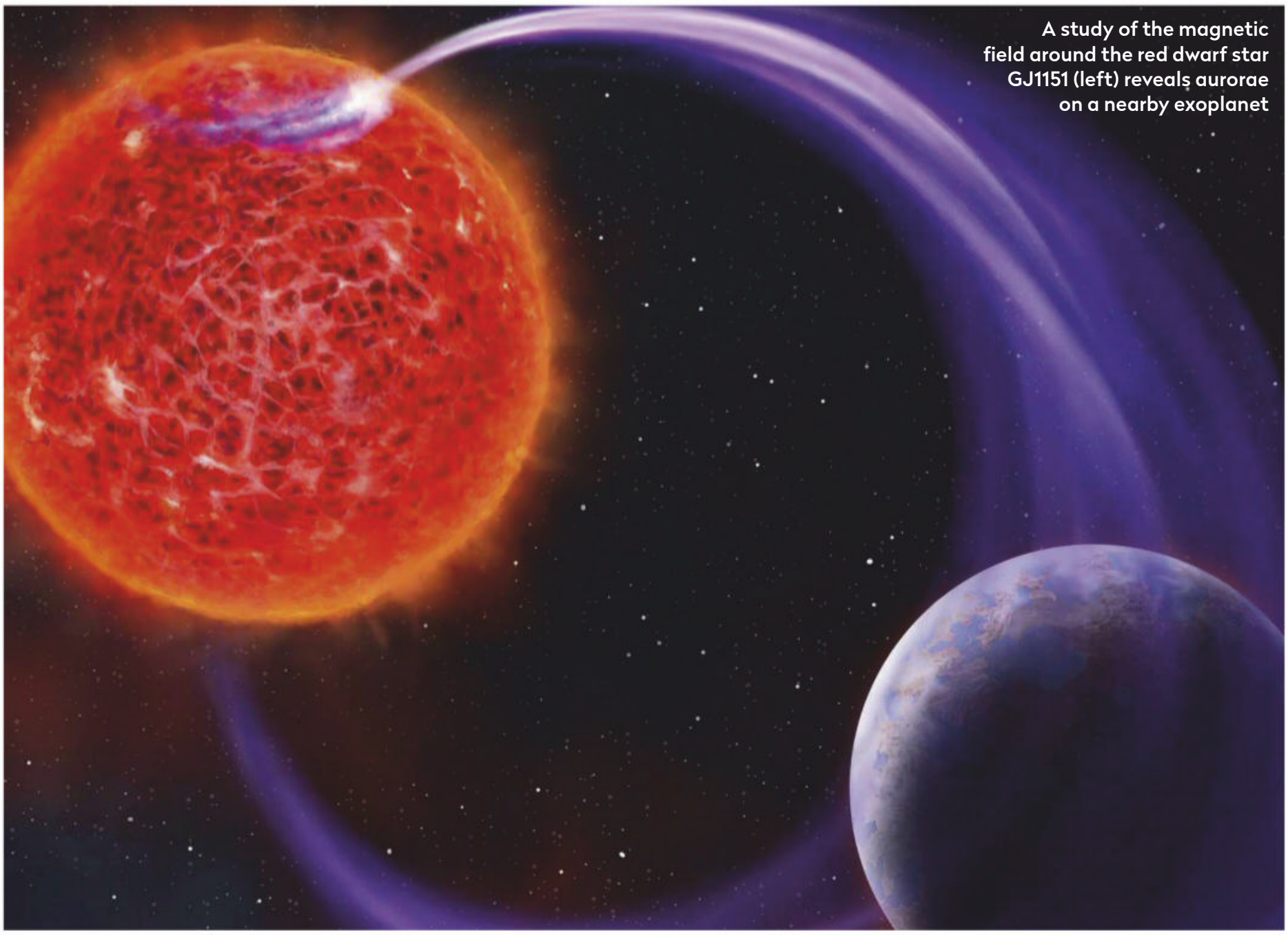
Comment

by Chris Lintott

The world's largest scopes rarely look at something as bright as Betelgeuse! The results were both stunning and intriguing, but they may not have happened without the contributions of thousands of amateurs, using the naked eye.

As the star faded, there was debate about how unusual its behaviour was. The answer came from the American Association of Variable Star Observers (AAVSO). Its Betelgeuse observations stretch back to the 19th century.

Red stars like Betelgeuse aren't easy to monitor, and it's so bright that there aren't good, nearby comparison stars. But, thanks to the work of AAVSO, astronomers have moved quickly to investigate this dip. A triumph, perhaps, for the old-fashioned art of looking at the sky.



A study of the magnetic field around the red dwarf star GJ1151 (left) reveals aurorae on a nearby exoplanet

DANIELLE FUTSELAAR (ARTSOURCE.NL), NASA/JPL-CALTECH, NASA, UNIVERSITY OF WARWICK/MARK GARLICK

Aurorae seen dancing around exoplanet

The find could help track down potentially liveable worlds

The tell-tale signature of aurorae have been detected around an exoplanet. A recent study of star GJ1151 revealed the hallmarks of its interaction with a planet's aurora – the first time such a phenomenon has been seen around a star – using radio observations taken by the Low Frequency Array (LOFAR) while hunting down planets in their stars' habitable zones.

GJ1151 is a red dwarf, meaning it is much smaller than our Sun but has a more intense magnetic field. "The motion of the planet through a red dwarf's strong magnetic field acts like an electric engine much in the same way a bicycle dynamo works," says Harish Vedantham from the Netherlands Institute for Radio Astronomy (ASTRON) who led the study. "This generates a huge current that powers aurorae and radio emissions on the star."

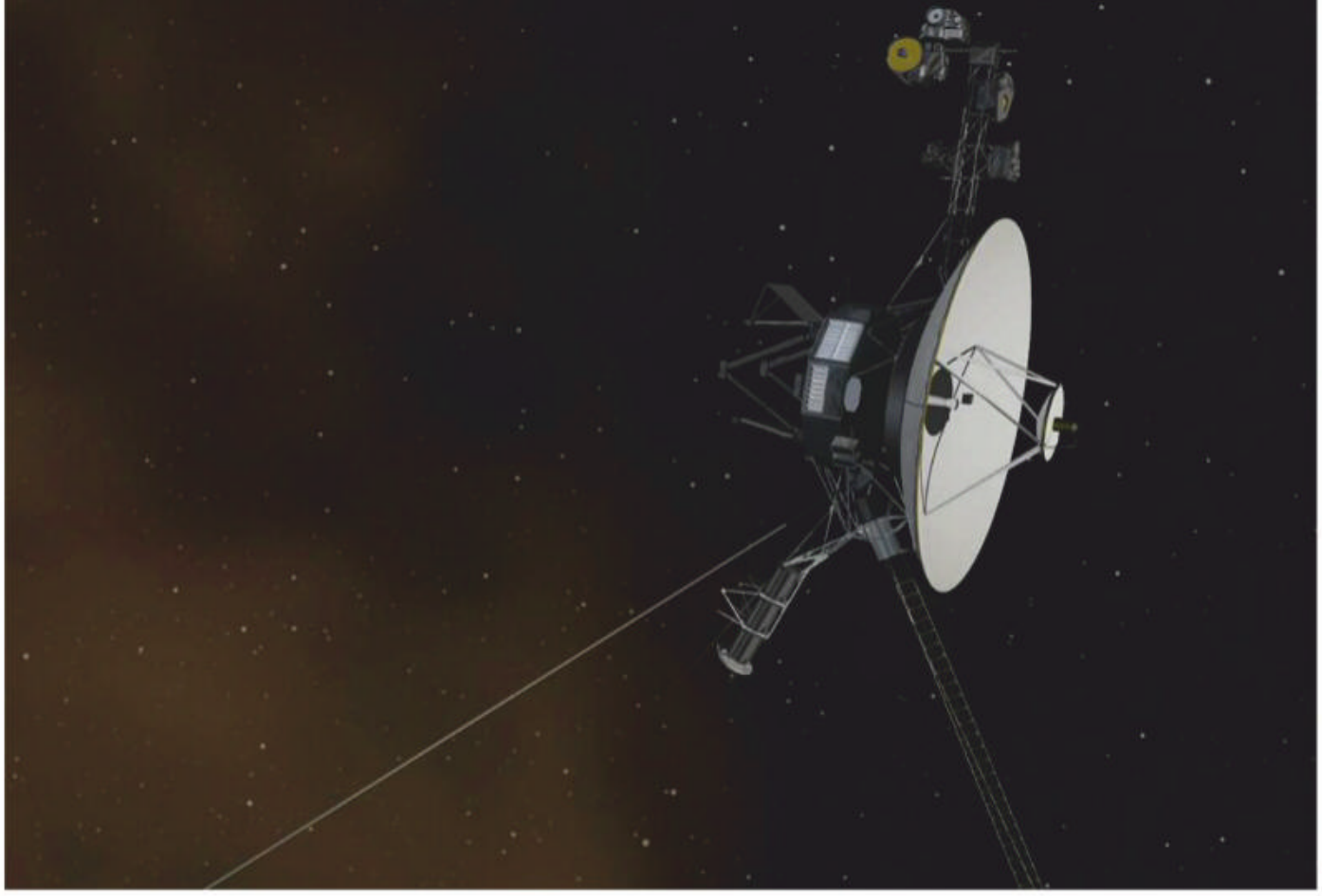
The Sun's weaker magnetic field means we can't see these radio emissions from our own star, though astronomers have picked up similar radiation between Jupiter and its moon Io.

"We adapted the knowledge from decades of radio observations of Jupiter to the case of this star," says Joe Callingham, also from ASTRON and co-author of the study. "A scaled-up version of Jupiter's relationship with Io has long been predicted to exist in the form of a star–planet system, and the emission we observed fits the theory very well."

As the effect can only be seen when the planet is very close to its star and red dwarfs are much cooler than our Sun, the region where these radio emissions occur is in the star's habitable zone, where liquid water can pool on the surface. As such, these auroral emissions could be used to track potentially habitable worlds. Astronomers will continue to hunt down these planets to investigate their suitability for life.

"The long-term aim is to determine what impact the star's magnetic activity has on an exoplanet's habitability, and radio emissions are a big piece of that puzzle," says Vedantham. "Our work has shown that this is viable with the new generation of radio telescopes and it's put us on an exciting path."

www.astron.nl



▲ Voyager 2 experienced a power overload deep in interstellar space, over 18 billion km away from Earth

Voyager 2 recovers from fault

The 42-year-old spacecraft is showing its age

Elderly planetary probe Voyager 2 has recovered from a glitch that prevented it from calling home after a scheduled manoeuvre on 25 January 2020.

The error arose when Voyager 2 was ordered to perform a routine 360˚ rotation to recalibrate its magnetic field instrument. When the flight team didn't hear back from Voyager on schedule, they realised they had inadvertently left the spacecraft running two power intensive systems at the same time.

Both Voyagers use nuclear powered generators which are slowly degrading, their available power generation dwindling by four watts every year. The extra load on the system caused the spacecraft to overdraw its power supply, meaning it couldn't operate its communications correctly.

Thankfully, both spacecraft have mechanisms to remedy such errors and Voyager 2 turned off instruments until it had enough power to call home.

www.nasa.gov

'Hidden Figure', Katherine Johnson dies

Katherine Johnson, the African American mathematician whose work for NASA in the 1960s was portrayed in the film *Hidden Figures*, died on 24 February 2020, aged 101. Johnson was a human computer, performing the many calculations needed to work out the trajectories for human spaceflight.

Johnson worked for NASA for over three decades, helping to calculate the flightpath of Apollo 11 and many other missions. Her work was so accurate that astronaut John Glenn – the first American to orbit the Earth – refused to fly until Johnson had checked the calculations. In 2015, President Barack Obama awarded her the Presidential Medal of Freedom, the nation's highest civilian honour.

Leading the way: NASA's brilliant research mathematician

"Ms Johnson helped our nation enlarge the frontiers of space even as she made huge strides that also opened doors for women and people of colour in the universal human quest to explore space," says Jim Bridenstine, NASA's current administrator. "At NASA we will never forget her courage and leadership and the milestones we could not have reached without her."

www.nasa.gov

NEWS IN BRIEF

Planet's 18-hour year

Astronomers have discovered an exoplanet that orbits its star in just 18 hours, the shortest year of any known planet. The world, NGTS-10b, detailed in a recent paper, is so close to its star it risks being torn apart by gravity. Astronomers will continue to watch the system to learn how long a planet can survive in such an extreme location.

Martian rover named

NASA's Mars rover, formerly known as Mars 2020, has a new name – Perseverance. The new moniker was selected by an essay contest, the winning suggestion coming from 13-year-old Alexander Mather. "We are a species of explorers, and we will meet many setbacks on the way to Mars," he wrote. "However, we can persevere."

Dying stars spin up asteroids

The bright radiation of a star heading towards its final white dwarf phase could give asteroids energy to spin themselves apart, potentially killing off nearby planetary systems. A study simulated the effect around our own star, finding that after its demise the destruction could reduce the asteroid belt to rubble in six billion years.

NEWS IN BRIEF

Wet Jupiter

Water makes up 0.25 per cent of Jupiter's atmosphere – around three times the levels in the Sun – according to recent observations from NASA's Juno spacecraft. Water helps control how planets grow. As Jupiter was the first planet to form, understanding how much water it has helps to determine how much was in the early Solar System.

Spaceport protested

Plans to build a Scottish spaceport have been criticised by environmental group Extinction Rebellion as reckless. Following an official submission to develop the site, which would launch up to 12 satellites a year, the group raised concerns that it could endanger nearby peatland, Flow County – which is in the running for World Heritage Site status.

Evidence of aliens?

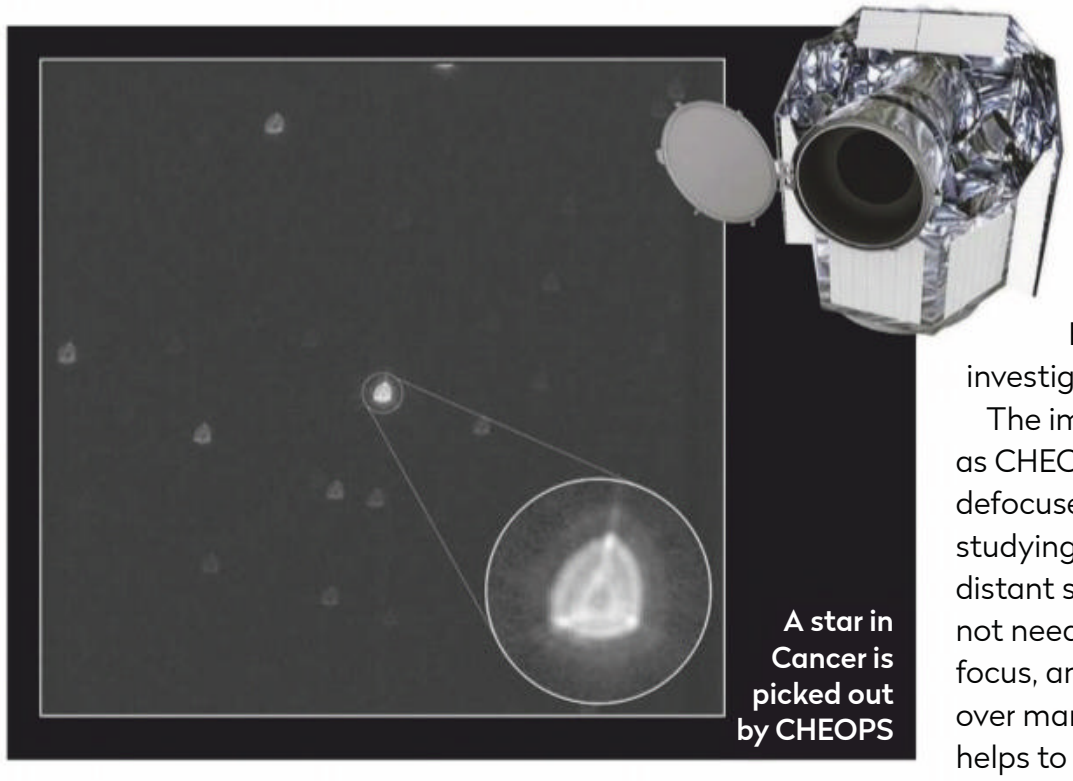
On 14 February, a Berkeley SETI Research Center project hunting for alien transmissions, Breakthrough Listen, made over two petabytes of radio and optical observations public. This is the second release by the project, this time making radio data from the plane of the Milky Way available. See **bit.ly/SETIdata** for details.

NASA/JPL-CALTECH/SWRI/MSSS/KEVIN M. GILL, @ESA/AIRBUS/CHEOPS MISSION CONSORTIUM, SPACEX, EXPRESS/STRINGER/HULTON ARCHIVE/GETTY IMAGES

BULLETIN

CHEOPS takes first image

A defocusing technique analyses a star field's overall light



A star in Cancer is picked out by CHEOPS

ESA's exoplanet investigating satellite, CHEOPS, has taken its first image in orbit after opening its cover on 29 January 2020. This initial photograph was intended as a test to ensure that the telescope was working correctly.

"When the first images of a field of stars appeared on the screen, it was immediately clear to everyone that we did indeed have a working telescope," says Willy Benz from the University of Bern and principal investigator of CHEOPS.

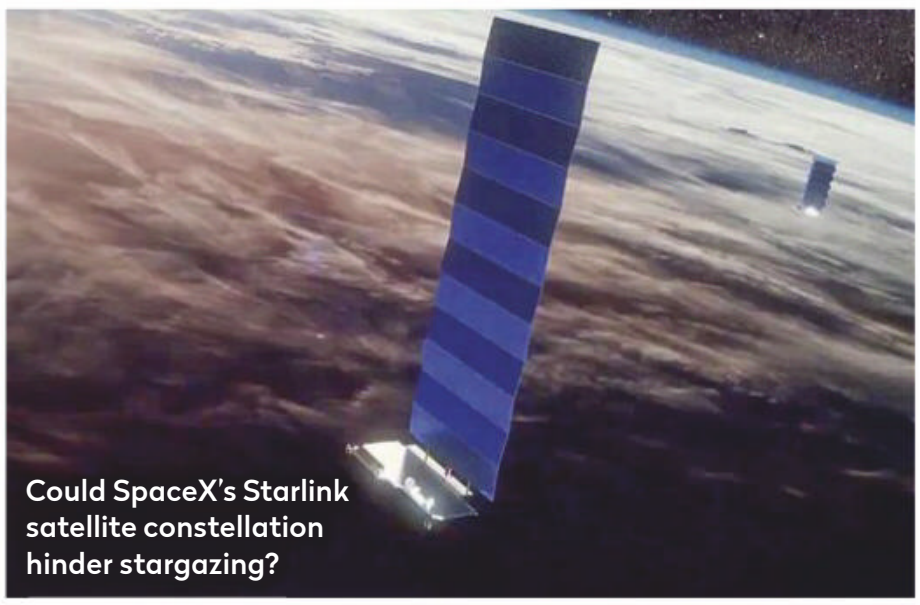
The image appears blurred as CHEOPS is deliberately defocused. As the telescope is studying the overall light from distant star systems, it does not need to have a sharp focus, and spreading the light over many pixels actually helps to improve precision.

"These initial promising analyses are a great relief and also a boost for the team," says Benz.

https://cheops.unibe.ch

IAU assesses 'mega-constellations'

The International Astronomical Union published a major review on 12 February, assessing the impact of 'mega-constellations' of satellites, such as SpaceX's Starlink, on the night sky. These networks consist of tens of thousands of spacecraft, working together to bring internet access to remote areas across the globe, but astronomers fear the reflectivity of these objects could destroy the view of the night sky.



Could SpaceX's Starlink satellite constellation hinder stargazing?

The report found that mega-constellation satellites are most visible close to the horizon as those high in the sky will be hidden in Earth's shadow during the night. Most satellites will only be visible to the naked eye while in a low orbit just after launch. Professional observatories, however, will still be able to see the spacecraft even after they reach their operational orbit. The Vera Rubin Observatory estimates that 30 per cent of its images taken during twilight with a 30-second exposure could be affected.

The IAU will present these findings to the UN Committee for Peaceful Uses of Outer Space (COPUOS) to bring the issue to the attention of world governments.

www.iau.org

Inspirational: broadcaster and writer Heather Couper was the first female president of the British Astronomical Association

Heather Couper dies at 70

Astronomy promoter and presenter, Heather Couper, has died on 19 February 2020 at the age of 70. During her long career she made several television appearances, including on *The Sky at Night,* enthusing people about the night sky and was the first female president of the British Astronomical Association (BAA).

"Some of my favourite *Sky at Night* programmes involved Heather, including one in which primitive CGI (computer-generated imagery) turned her into various sorts of star before plunging her and Patrick into a black hole," recalls *The Sky at Night* presenter Chris Lintott. "Her determination to have fun in every circumstance will be much missed."

Born on 2 June 1949, Couper's love of the stars developed as a young child when she spotted a green shooting star in the sky. She almost gave up the hobby in her teens, before realising astronomy wasn't just for "shambolic old men in tweed jackets anymore". Seeking encouragement, she wrote to *The Sky at Night* presenter Patrick Moore, who reassured her that "being a girl is no problem at all" in her path to becoming an astronomer.

"She wrote to me... and said, 'Is there any future for me in astronomy?' and I said 'of course there is,' and I tried to give her a hand," he later recalled.

After a year gaining her Maths A-level and analysing data at Cambridge Observatory, Couper undertook a degree in astrophysics at Leicester University. Here, she met Nigel Henbest, who would become her long-term professional partner and friend. In the 1980s, the pair founded Pioneer Productions to create and present programmes that promoted science and astronomy to the wider world, with a particular aim of encouraging women to join the field. Together with Henbest, Couper co-wrote over 40 popular-level books on astronomy, as well as writing a regular column for the *Independent*.

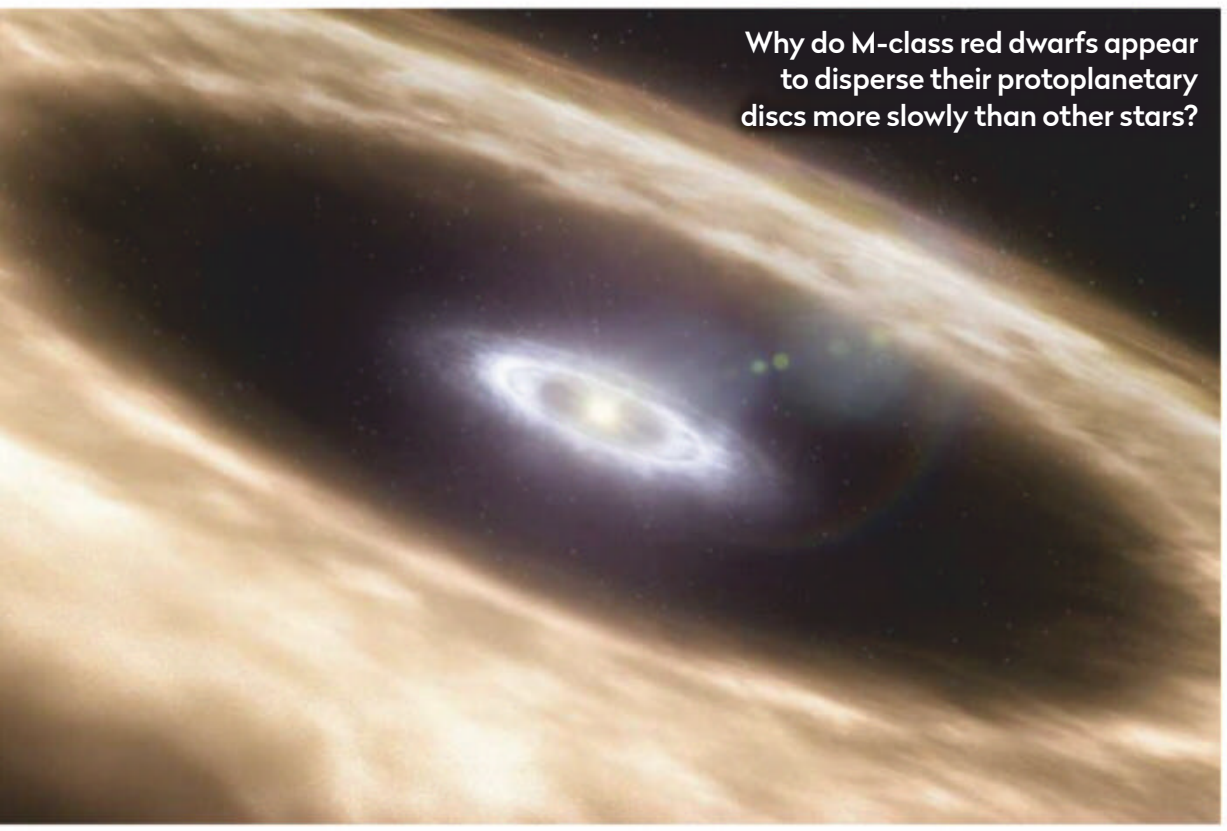
She was an active member of the BAA and was elected to succeed Patrick Moore as its president in 1984, the first woman to hold the position.

"She was a very popular president and an excellent speaker," recalls Alan Dowdell who served with her on the BAA council and was a personal friend. "I do remember that when she was president she was invited for tea with the Queen. As a great dog lover, she took pleasure in asking the Queen about her corgis.

"She was great company and always encouraged members to join her after the meeting in the local wine bar where astronomical discussions continued until quite late. We will all miss her."

Our experts examine the hottest new research

CUTTING EDGE



Why do M-class red dwarfs appear to disperse their protoplanetary discs more slowly than other stars?

ESO X 2

The planetary systems that never grow up

'Peter Pan' dust discs persist around stars after they should have dispersed

There's something strange about the star WISEA J080822.18-644357.3. And it's not just the star's extreme mouthful of a name. J0808 is an M-class, low-mass red dwarf star in the Carina association, over 330 lightyears away. It exhibits an extreme infrared excess – this means that the J0808 system is giving off far more thermal energy than you would expect from its visible brightness. The normal reason for this is that newly formed stars are often still surrounded by a protoplanetary disc of gas and dust, which warms up in the young starlight and emits the extra infrared radiation.

The strange thing is that J0808 isn't really all that young – it formed about 45 million years ago. It was previously thought that any primordial disc of gas and dust, or a secondary debris disc created during the later stages of planetary formation, ought to have long since dispersed by this time. For example, a Spitzer Space Telescope survey of almost 200 newly formed stars didn't find a single one that still had a protoplanetary disc after 10 million years.

Steven Silverberg, at the MIT Kavli Institute for Astrophysics and Space Research, and his colleagues have dubbed such star systems that apparently refuse to grow up as 'Peter Pan' discs. Delightfully, the researchers even formally cite the author of *Peter Pan* (1904), JM Barrie, in the paper.

J0808 had already been recognised as an oddity by its late infrared excess, but now Silverberg's team report on a handful more examples of such Peter Pan discs. They were able to find them with the help of an army of volunteer astronomers. These new Peter Pan systems were discovered by the Disk Detective project; a citizen science collaboration between NASA and Zooniverse, run by *The Sky At Night*'s very own Chris Lintott. The citizen scientists inspect images of star-forming regions taken by the Wide-field Infrared Survey Explorer (WISE) and indicate any circumstellar discs they think they can see. These candidates undergo further investigation using data from other ground- and space-based telescopes – such as Gaia, TESS, and the Gemini Observatory – to determine their distance and age, and to perform spectroscopy.

Young at heart

"These new 'Peter Pan' systems were discovered by the Disk Detective project – a citizen science collaboration"

The increasing number of Peter Pan disc discoveries may indicate that they're actually relatively common, but a big mystery remains about why these systems are refusing to grow up?

Silverberg considers a number of different possible explanations that could account for these very late protoplanetary discs, including the possibility that we're seeing dust from the outer system migrating in to the star and warming up, or perhaps we're witnessing the cataclysmic aftermath of colliding protoplanets. But the confusing thing is that – alongside the vast amounts of dust – these Peter Pan discs also seem to hold gas. Perhaps the simplest explanation then, concludes Silverberg, is that for some reason these M-class red dwarf stars just don't disperse their gas-rich protoplanetary discs as quickly as other stars. And this is exciting, because it means we've still got something fundamental to understand about the development of red dwarf stars.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Peter Pan Discs: Long-lived Accretion Discs Around Young M Stars* by Steven M Silverberg et al.
Read it online at https://arxiv.org/abs/2001.05030

Observing a stellar chameleon

Astronomers have been watching an unusual star for over 20 years

Prof Chris Lintott is an astrophysicist and co-presenter of *The Sky at Night*

We're so used to the astronomical world being static and unchanging that even small alterations, like this year's fading of Betelgeuse in Orion, can be both surprising and somewhat unsettling. For some objects, though, change is just a way of life, and that's certainly true of Sakurai's Object, the subject of this month's paper.

It's now more than 20 years since the Japanese amateur astronomer Yukio Sakurai noticed what he thought was a nova in the constellation of Sagittarius. Follow-up observations soon showed it to be something rather more interesting. It appeared to be a normal supergiant star, but its spectrum kept changing and, in 1997, Sakurai's star began producing a shell of carbon dust.

"It's more than 20 years since amateur astronomer Yukio Sakurai noticed what he thought was a nova in Sagittarius"

Gathering dust

By 1999, less than three years after that initial discovery, this dusty carapace completely blocked the view of the star itself, a situation which persists to the present day. This dust is produced in the star itself, and in prodigious quantities; early observations suggest more than three Earth masses of the stuff was produced each year.

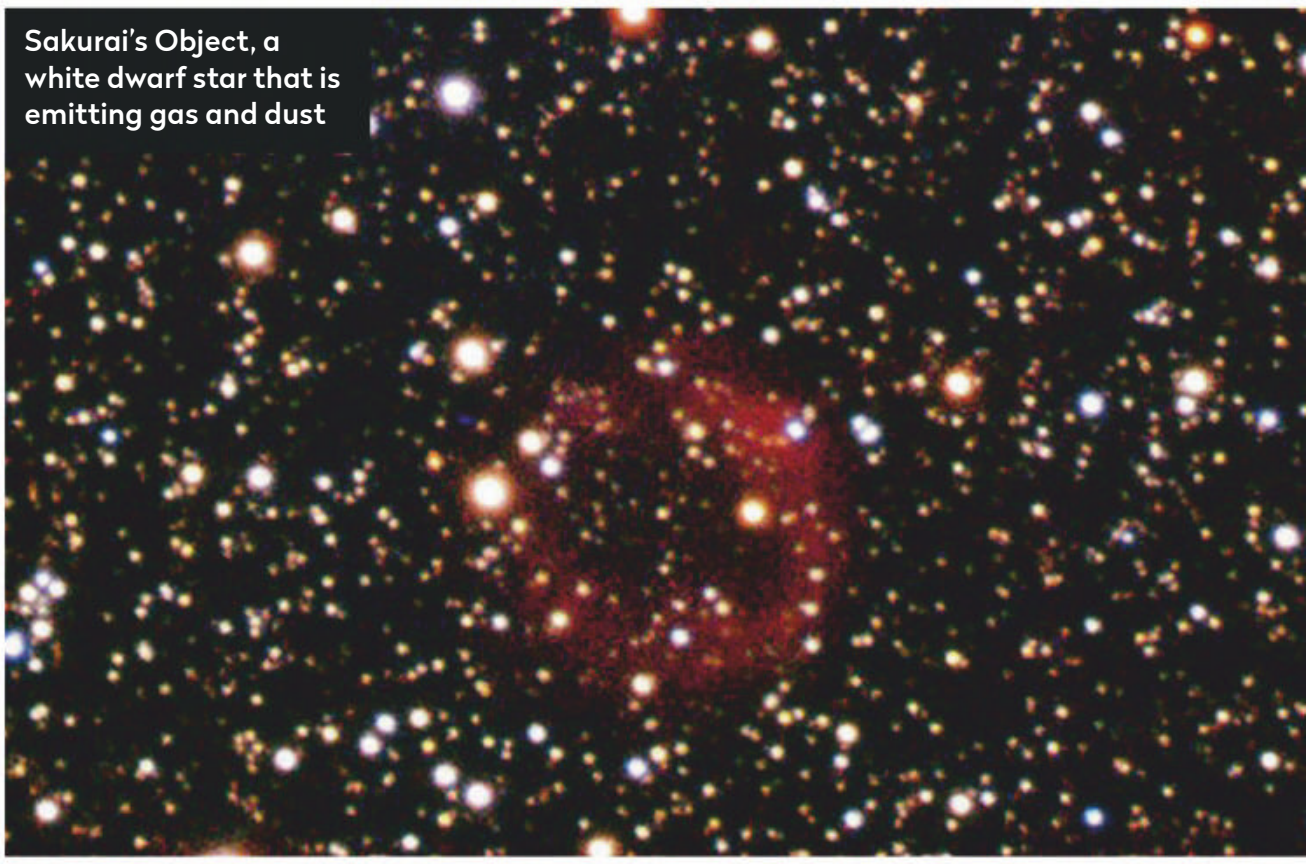
The explanation for this behaviour is that Sakurai's Object is in a very particular stage of its life, having exhausted the hydrogen and helium fuel available at its core. Instead, fusion is taking place in a shell of material around the star's core, and this inherently unstable situation leads to the star's wandering in brightness. The object is currently in a state in which it is brightening, but the disruption has probably dredged up heavy elements such as carbon from the inner layers.

It's from these heavy elements, the by-products of previous epochs of star formation, that the dust that obscures the star is being assembled.

Putting together more than 20 years' worth of observations, the authors of this month's paper give themselves a grandstand seat from which to watch this part of a star's life. Along with the dust, observations of molecules such as hydrogen cyanide (made up of a single atom each of hydrogen, carbon and nitrogen) help them understand the physical conditions around the object itself.

These observations show that things are still changing around the star. Between 1998 and 2016, the dust has cooled from over 900°C to –90°C or so. In the years to come, it will cool further and the light from the star itself should become visible once again. At some point, the source will reach its maximum brightness, before fading again. Such cycles will continue until so much mass is lost from the star that fusion is no longer possible, leaving behind a fading white dwarf and a briefly beautiful planetary nebula.

Such a nebula has already been seen, centred on Sakurai's Object, indicating that this cycle of mass loss goes back more than 10,000 years. This unusual object shows us the complex lives that small stars – perhaps no more massive than the Sun – undergo at the end of their lives. During a single lifetime it's possible to watch such stars alter and change and this fascinating, albeit dusty, stellar chameleon is worth keeping an eye on.

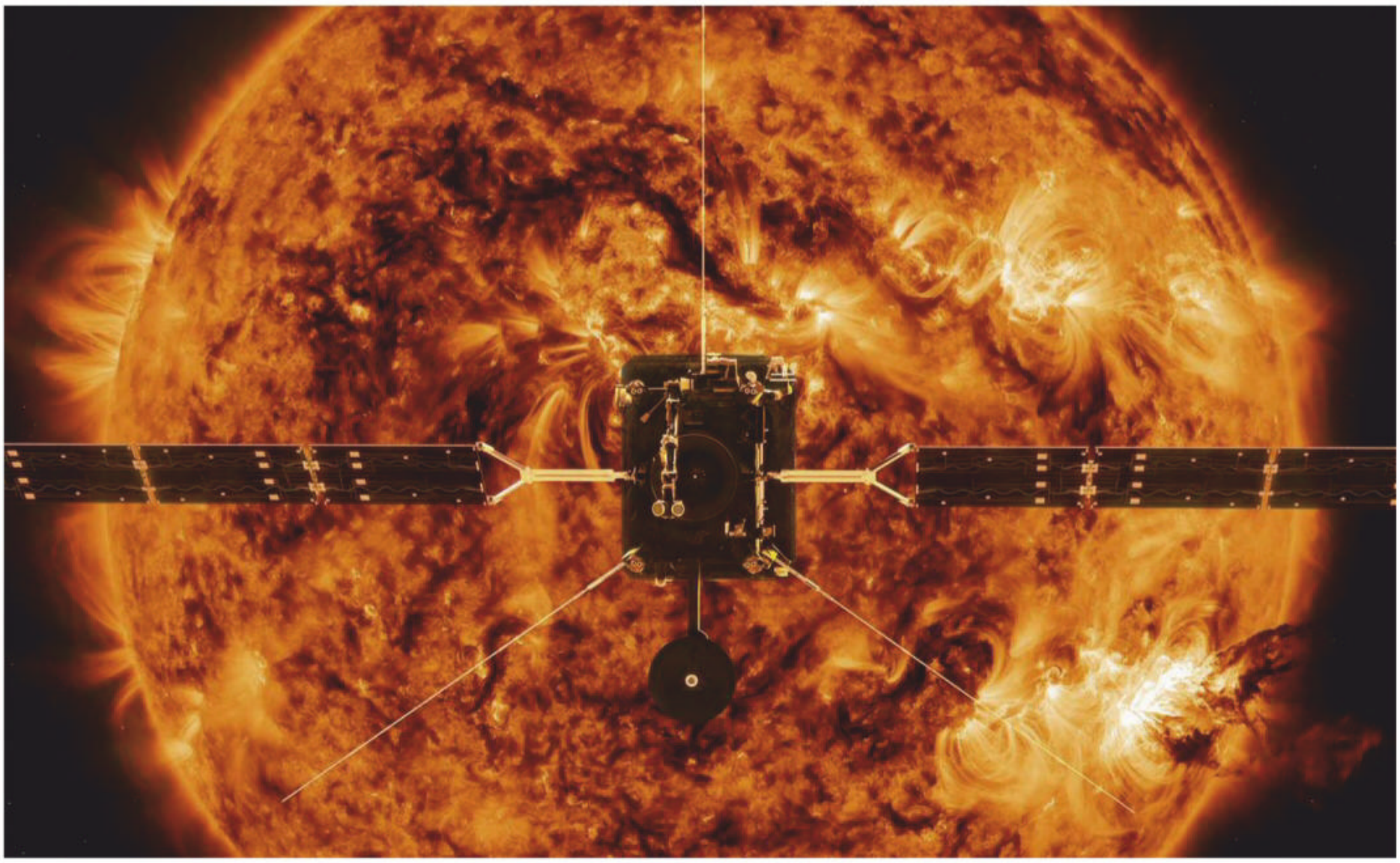


Sakurai's Object, a white dwarf star that is emitting gas and dust

Chris Lintott was reading... *The infrared view of dust and molecules around V4334 Sgr (Sakurai's Object): a 20–year retrospective* by A Evans et al.
Read it online at: https://arxiv.org/abs/2002.00907

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



▲ **Secrets of the Sun: ESA's Solar Orbiter will explore our star in more detail than ever before**

ESA/ATG MEDIALAB/NASA/SDO/P. TESTA (CFA), KIRSTYPARGETER/ISTOCK/GETTY IMAGES, ESA/S. CORVAJA

April's episode of *The Sky at Night* looks at ESA's Solar Orbiter, and speaks to **Helen O'Brien** about her work on the project

Solar Orbiter, the European Space Agency's new Sun explorer, blasted off from Cape Canaveral in February. It is now heading for an encounter with Venus soon after Christmas. These encounters (there will be eight with Venus and one with Earth over the 10-year mission) will be instrumental in helping the spacecraft slow down enough to balance against the Sun's gravity, and crucially also 'catapult' the spacecraft out of the ecliptic plane around the Sun (where all the planets orbit), allowing the first views of the Sun's poles. This unique orbit, combined with a suite of scientific instruments offering remote sensing of the Sun's surface and measurements of the solar wind particles streaming off the Sun, will give scientists the data they need to understand how energy is transferred from our star into the Solar System.

The spacecraft and instruments have taken over a decade to design and build, going through multiple prototypes and extensive testing before getting to the launch pad. The competing demands of the instruments and environment have generated challenge after challenge for ESA which has managed the project, Airbus in Stevenage which built the spacecraft and the 10 instrument teams from across Europe and the US. And there is little room for error. A speck of dust on a camera lens at launch would stay there forever, getting baked onto the lens surface and obscuring the view. A stray magnetic field generated by an instrument circuit or the wrong choice of material, would swamp the detailed measurements of the solar wind. In the vacuum of space, the heat shield which protects the spacecraft from the extreme solar radiation (13 times more intense than experienced by satellites in Earth orbit) must radiate heat to avoid melting, while at the same time, sensors out on the boom in the heat shield's shadow are in perpetual night time and must be heated to stay warm.

Lift off marks a huge moment in the lives of the people working on this project. The first hint at what

Helen O'Brien is a space instrument engineer at Imperial College, London

we can expect will come over the summer, when the spacecraft reaches approximately 0.5 AU (where 1 AU is the distance from the Earth to the Sun) and scientists get their first chance to try out coordinated measurements sensing the Sun's surface and measuring what is thrown out into space. The real excitement will come in spring 2022, with the spacecraft passing within 0.3 AU of the Sun. At this closest approach, Solar Orbiter will be able to focus on one region of the Sun for about a month, watching features evolve, and simultaneously sampling the magnetic field and particle population passing the spacecraft. This pristine solar wind, sampled close to the source, combined with eyes on the Sun itself, will provide unprecedented insights into the connection between the Sun and its extended atmosphere that engulfs the whole Solar System. The Sun is incredibly dynamic: huge explosions driven by magnetic field interactions unleash energetic particle populations capable of harming astronauts, knocking out satellites and causing problems with power grids here on Earth. Solar Orbiter will deliver new measurements to help us understand how these processes work, and ultimately make better predictions of space weather to keep our astronauts and technology safe.

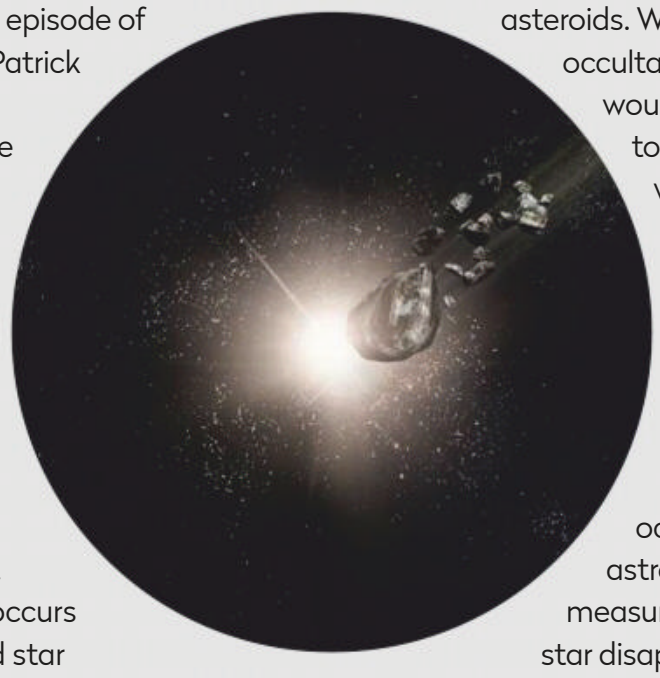
Looking back: The Sky at Night

5 April 1978

On the 5 April 1978 episode of *The Sky at Night*, Patrick Moore talked with astronomer George Taylor from the Royal Greenwich Observatory. Since 1952, Taylor had been working on a new method to measure the size of asteroids using occultations.

An occultation occurs when a foreground star passes in front of a background one, temporarily blocking out its light. By measuring the length of time the star blinks out, astronomers can gauge the size of the asteroid passing in front of it.

Taylor was able to compute the times when occultations were likely to occur for the planets and 80 of the largest asteroids. When a potential occultation was due, he would pass the news to observatories who would pin down the orbits of the asteroid more precisely to determine if an occultation would happen. During the occultation itself, astronomers would measure how long the star disappeared for. Using at least two measurements from different locations, Taylor could work out the size of the passing asteroid.



▲ We can learn much about asteroids by measuring occultations

Measuring occultations has become a popular project for many amateur astronomers. With enough people working together at disparate locations, it's possible to map out the rough shape of the asteroid's shadow as well.

Here comes the Sun

On 9 February 2020 ESA's Solar Orbiter launched on its journey to the Sun. Armed with a suite of instruments, the orbiter will study how the stream of charged particles emanating from the Sun, known as the solar wind, affects and influences the planets and other bodies of the Solar System. This month *The Sky at Night* team go behind the scenes to learn more about the spacecraft and this exciting mission.

BBC Four, **12 April**, 10pm (first repeat BBC Four, **16 April**, 7.30pm)
Check www.bbc.co.uk/skyatnight for subsequent repeat times

Solar Orbiter is on its way to study the Sun

Emails – Letters – Tweets – Facebook – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

SPECIAL PRIZE

Four Philip's books *and* a Sky-Watcher Infinity telescope!

PHILIP'S

This month we've got a special bumper prize, which includes Sky-Watcher's fun Infinity 76P telescope, PLUS Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Mark Thompson's *Stargazing with Mark Thompson* and Heather Couper and Nigel Henbest's *2020 Stargazing*.

Winner's details will be used by Immediate Media and passed on to Octopus Publishing to fulfil the prize.

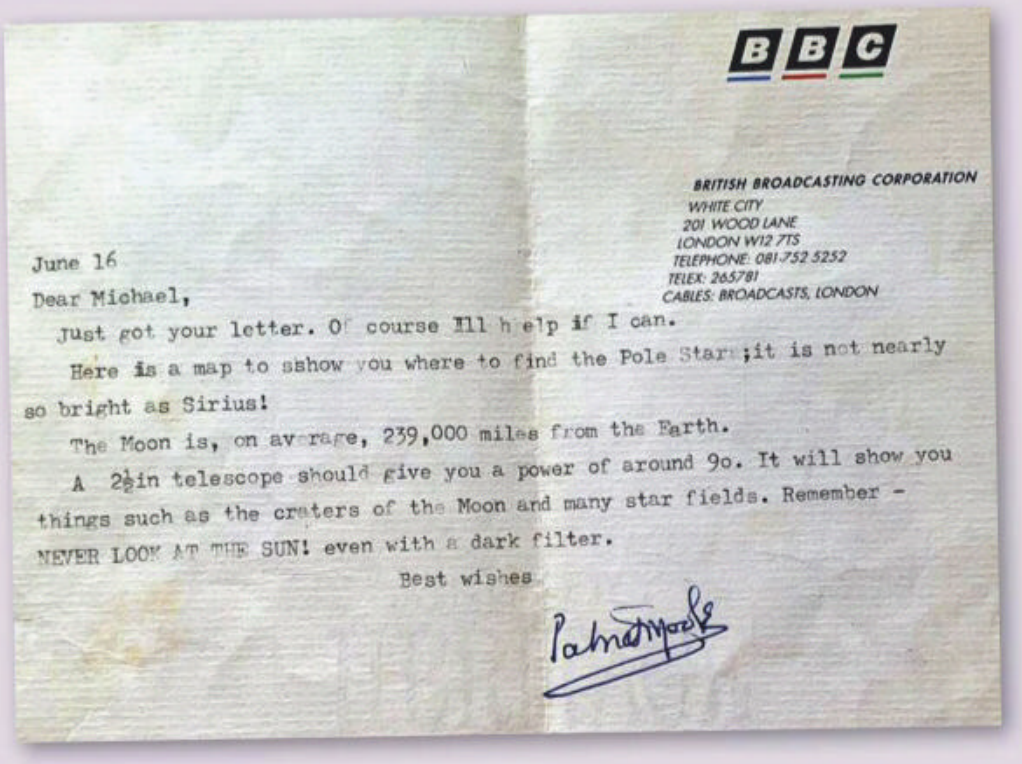
MESSAGE OF THE MONTH

Letter from a legend

I was going through some old stuff at home recently and I found this letter. I was around 11, obsessed with astronomy and wrote to Patrick Moore using the address for BBC One's Saturday morning magazine show *Going Live!* About two months later, I got his reply. It even has repeated letters from his broken typewriter. It inspired me so much.

Michael Blair, @MichaelPBlair via Twitter

Thanks for sharing your find, Michael. Patrick was a prolific letter writer and did so much to encourage people to look up and discover the cosmos. **– *Ed***



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June 16

Dear Michael,

Just got your letter. Of course I'll help if I can.

Here is a map to sshow you where to find the Pole Star;it is not nearly so bright as Sirius!

The Moon is, on average, 239,000 miles from the Earth.

A 2½in telescope should give you a power of around 90. It will show you things such as the craters of the Moon and many star fields. Remember - NEVER LOOK AT THE SUN! even with a dark filter.

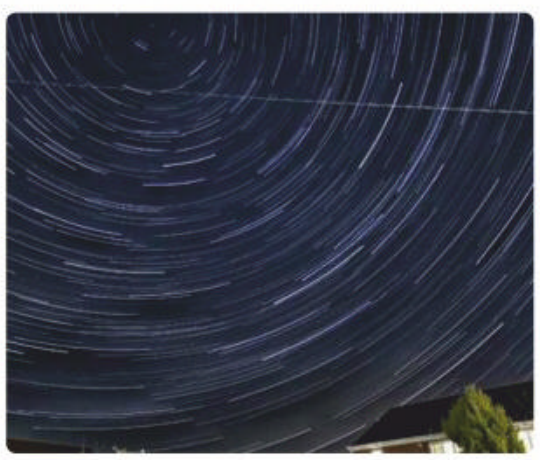
Best wishes

Patrick Moore

▲ **Top tips: Patrick Moore's reply to Michael includes helpful advice about finding the Pole Star and avoiding the Sun**

Tweets

John M
@johnmason1971 • Jan 22
Took advantage of the clear night, so left the phone on a tripod for an hour. Looking North, from North Tyneside. #astrophotography #stargazing #startrails #smartphone #p20pro @VirtualAstro @skyatnightmag @AwesomeAstroPod



Each to their own

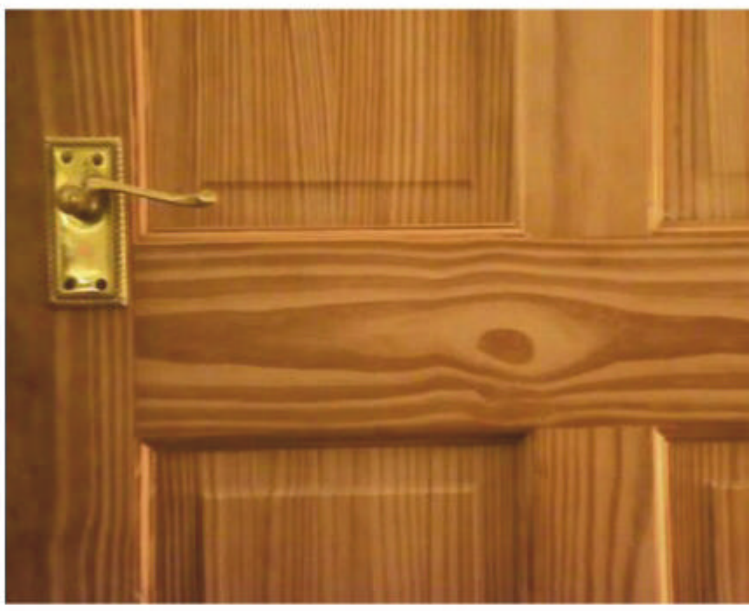
I read with interest the *Field of View* article in the February 2020 issue regarding remote astronomy, in particular the comment relating to "opposition from some quarters". Although I've not had the pleasure of indulging in remote astronomy, I think it's a brilliant concept, giving access to professional grade equipment from some of the darkest skies on Earth, all from the comfort of your home – thousands of miles away in most cases. I can only imagine those folk who oppose such an idea are of a similar mindset to those who think, for example, that using image manipulation programs to get the very best from an astro image is cheating. Whatever one's hobby, is it not best to use whatever technology is available to augment, improve and enhance one's skills and enjoyment, often at a very reasonable price, and sometimes, totally free?

Rich Broome, via email

A familiar spot?

I spotted a reminder of Jupiter's Great Red Spot on my living room door and wondered if any other readers of *Sky at Night* magazine has seen similar sights? It is a good talking point for visitors.

Paul Lytte, Moniaive, Dumfries and Galloway ▸



Remembering Heather Couper

Many of you got in touch via Facebook and Twitter following news of the death of astronomer, author and TV presenter Heather Couper (see obituary on page 15)

FACEBOOK

Vikki Kim Heather Couper got me into the stars and Universe when I was a youngster! RIP Heather another bright star in the sky.

Sonja Charters I met her on an astronomy trip to watch the total eclipse in Hawaii many years ago. Sleep well among the stars Heather.

David Greensmith Sad news. I think she was the first woman astronomer I ever saw on TV.

Graham Woodall May she rest in peace. I really enjoyed watching her enthusiasm for space when I was growing up.

Mark Plas I loved the series *The Planets*, presented by Heather, which aired in the Netherlands in the late 1980s and early '90s.

Cate Walker Lovely voice, superb presentation skills and amazing knowledge which transformed the way we looked at the stars and space. What a great shame she died so 'young'. Thank you Heather.

Stuart Glenwright Heather, via her wonderful and contagious enthusiasm was along with Patrick Moore the reason I got into astronomy. She was a wonderful communicator and I loved the story she told about Patrick getting her letter and encouraging her. I'm sure she realised how widely loved and admired she was, a true pioneer. I had expected her to take over *Sky at Night* when Patrick left us, she would have been perfect. She could explain astronomy and cosmology to an audience in ways anyone could understand.

TWITTER

David Griffin @griffolla Sad news. I'd been listening to her *Cosmic Quest* series on Radio 4 most nights before bedtime for about three years now. It's fascinating and calming.

Alan Dyer @amazingskyguy So sorry to hear the news. Heather was one of the great next generation of science popularisers following the lead of Sir Patrick Moore. She will be missed.

Dean Jones @dean069 I used to watch her back in the '80s. She and Sir Patrick made me love astronomy

Dr Patricia M Lewis @PatriciaMary I invited her to Geneva to @UNIDIR Annual Space Conference back in the day. She was very open about so many important and difficult issues – especially for women in science.

Gareth Murtagh @garethjmurtagh What sad news, I loved her series *The Planets* made for Channel 4 in the late '80s, I can still hear the theme song!

Joanna Kate Wright @joannakwrighty I am so sad to hear this. Heather Couper showed a generation of children in the 1980s and '90s that women were part of science and astronomy. That gentle and knowledgeable voice will be missed.

Debbie Jamieson @DebbieJamieso11 I loved watching the TV series *Heavens Above*, which piqued my interest in astronomy as a child.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

After cataract surgery, I bought a Celestron Inspire 80AZ telescope with a Sky-Watcher SP 32mm eyepiece and a Moon filter. What can you suggest for me to get the most out of my telescope?

DARREN LAMBERT

▲ **The Inspire 80AZ will work better with 20mm and 32mm eyepieces**

The Celestron Inspire 80AZ telescope is suitable as a beginner's telescope. However, the 10mm and 20mm eyepieces supplied with the telescope are Kellners, which are an older three-element design. In this price range they will be somewhat inferior to the more modern four-element design of Plössls.

You'd be better off using the 20mm version, as recent experience has found the 10mm version produces quite poor results, so you will likely be disappointed with the view. Your 32mm Sky-Watcher eyepiece will also serve you well.

In the wake of your recent surgery, I applaud your purchase of a Moon filter to tame down this rather bright object.

The altazimuth mount itself is very easy and pleasant to use but you could further damp down vibrations by increasing the stability of the tripod: simply suspend a weight from the underside the tripod head; a bag filled with sand is good for this.

Steve's top tip

What do the numbers on binoculars mean?

Binoculars are excellent for observing the night sky but it is important to buy a pair that you can handle while maintaining a good grasp. High magnification instruments are more difficult to hold steady.

Binoculars are always marked with two numbers, for example 10x50. This means that the magnification is 10x and the aperture is 50mm. There is often additional information describing the field of view, for example 80m at 1,000m indicates you'll be able to see an area 80m across 1,000m away. You can convert the field width to degrees, a more useful measurement for astronomy, by copy-pasting the following formula into a cell on a spreadsheet:

=DEGREES(ATAN(Field width in metres/2000))*2

Steve Richards is a keen astro imager and an astronomy equipment expert

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IMMEDIATE MEDIA CO

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Andromeda test

▸ I recently purchased a 6-inch Schmidt Cassegrain Telescope (SCT) and decided to get a second, faster scope to do wide-field observing with the same mount. I settled on a 4-inch refractor. When I turned my Go-To mount to the Andromeda Galaxy and observed with both scopes I was surprised to find the view through the 4-inch refractor was more impressive. I know that a wider field of view is preferable for an object like M31, but I thought that with an extra 2 inches the SCT would give better views. I wondered whether the SCT's secondary mirror 'cancels out' its extra 2 inches, or whether it's just a matter of preference?
Fionn Daly, via email


M31 will often look better with a wider field of view

Tweets

StrollingShuttereyes
@strollingshutte • Feb 10
A Bridge Divides: The Ice Fisherman and the Super Snow Moon. After weeks of clouds, perfect weather to photograph the Moon rise over the St. Croix River. Enjoy! @sony @WDNR @mndnr @ROGAstronomers @skyatnightmag @accuweather @SCVMag #supersnowmoon #moon #landscape #icefishing

SOCIETY IN FOCUS

'Keeping It Simple, Straightforward, and Accessible' (#KISSAstro) is one of the main tenets of **Highlands Astronomical Society** (HAS), the Inverness-based astronomy club with its own public access observatory next to the Culloden battlefield.

With a 14-inch Meade Schmidt-Cassegrain telescope under the dome, the Jim Savage-Lowden Observatory is our pride and joy: we host public and members' observing sessions there on most weekends from September until March. A state-of-the-art astro-camera links the scope to a warm room where people can view deep-sky objects in colour. The facility has opened up practical astronomy to young children and the disabled.

HAS was formed in 1994 and has over 60 members, including a vibrant 'Youngstars' section for 8–14 year olds. The club meets from 7.30pm on the first Tuesday of each month in the Smithton Free Church Café for an astronomy-related talk, tea and the eagerly-awaited monthly club news, with details of our target constellation for the month and our own astrophotos. There's

▲ HAS chairman Eric Walker pictured at a February event with members Sharon Lloyd and Rhona Fraser

then a practical astronomy session or a discussion indoors to end the evening.

HAS is very active in public outreach. Our members give talks and observatory tours to schools and local youth groups, deliver lectures at science festivals and host pop-up observatory sessions (including solar) all over the local Highlands area, including the Belladrum Tartan Heart Festival, every summer. We also coach new astronomers and give practical advice on equipment, astrophotography and what to observe.
Eric Walker, chairman, HAS
▸ www.spacegazer.com, @highlands.astro

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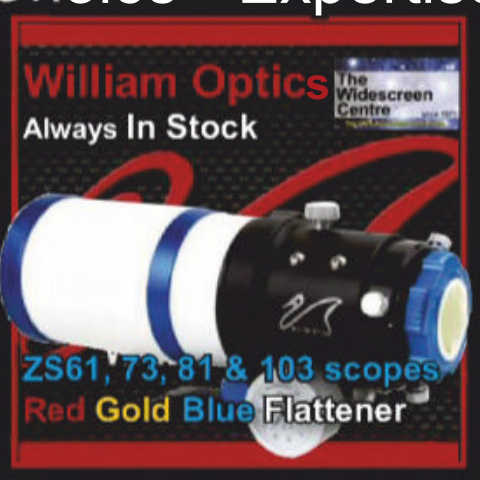

NGC7635 image by Gordon Haynes www.imagingtheheavens.co.uk

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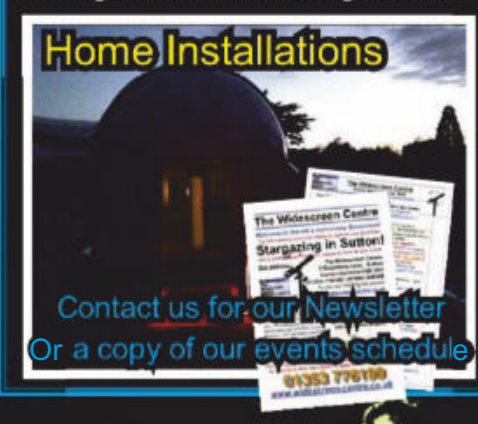

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www.practicalastroshow.com

Our pick of the best events from around the UK

WHAT'S ON

KELLING HEATH STAR PARTY, EDINBURGH SCIENCE FESTIVAL X 4

Kelling Heath Star Party

Weybourne, Norfolk, 20–27 April

If the clouds stay away, this should be a fun way to enjoy north Norfolk's dark skies. The week-long event often hosts hundreds of amateur astronomers, and newcomers are welcome. Astro equipment vendors will also be on site. **www.starparty.org**

Astrometry talk

Bath Royal Literary and Scientific Institution, Bath, 3 April, 7.30pm

The pioneering efforts to make a 3D map of our Galaxy are explored in this talk by ESA/Gaia project scientist Michael Perryman. He leads on Hipparcos and Gaia, two missions to measure the position and movements of a billion stars. Visitors £5; members/students £2. **www.brlsi.org**

Stargazing at Low Force Waterfall

Bowlees Visitor Centre, County Durham, 9 April, 9.30pm

A beautiful dark-sky site and the drama of the Low Force Waterfall are the backdrop for this night of stargazing. Binoculars are provided as well as expert guidance, and visitors get an information sheet and sky map to take home. Tickets £15 **www.stargazingnights.co.uk/events**

Kielder stargazing

Kielder Castle, Northumberland, 14 April, 8.30pm

Join amateur astronomer Bruce Ferguson at Kielder Castle for dark-skies observing. There's an astronomy software demonstration before outside observing, weather permitting. Tickets £5. Book via **enquiries@natureholiday.co.uk**

PICK OF THE MONTH

▲ **Capital benefits: the whole family can enjoy a range of scientific activities around the city**

Edinburgh Science Festival 2020

Various venues, Edinburgh, 4–19 April

This year the Edinburgh Science Festival is hosting a range of science workshops, talks and demos across the Scottish capital. While the 2020 festival's theme is 'Elementary' – exploring Earth, Air, Fire, Water and the Aether – many events will also take a look at the wider Universe.

Artist Luke Jerram's 7m-wide model of Earth – constructed using NASA imagery – comes to Edinburgh for the first time. It's 1.8 million times smaller than the real thing and will be available for drop-in visits throughout the festival.

This year's talks include Exploring Space Science, a discussion of how the workings of the cosmos impact daily life on Earth; What is Out There?, exploring the potential for life beyond Earth; and Interstellar Medicine, looking at how procedures can be adapted in zero gravity.

Plus, astronomers Luke Barnes and Geraint Lewis reveal how the Universe works in The Cosmic Revolutionary's Handbook; and Satellite's Eye View takes a look at how satellites have changed life on Earth. **www.sciencefestival.co.uk**

The Planets 360°

Armagh Planetarium, Armagh, 17 April, 7pm

This one-hour show is a reimagining of Holst's *The Planets*, using the full dome to create an immersive 360˚ art, music and science extravaganza. Tickets £7. **bit.ly/armaghobservatoryplanetarium**

Lyrids evening

EAARO Space Operations Centre, Cambridgeshire, 21 April, 8.30pm

Visit a former RAF airfield, now home to the East Anglian Astrophysical Research Organisation, to use radio telescopes to view back scatter reflections from the Lyrid meteor shower. Tickets £5.98. **bit.ly/eaaro**

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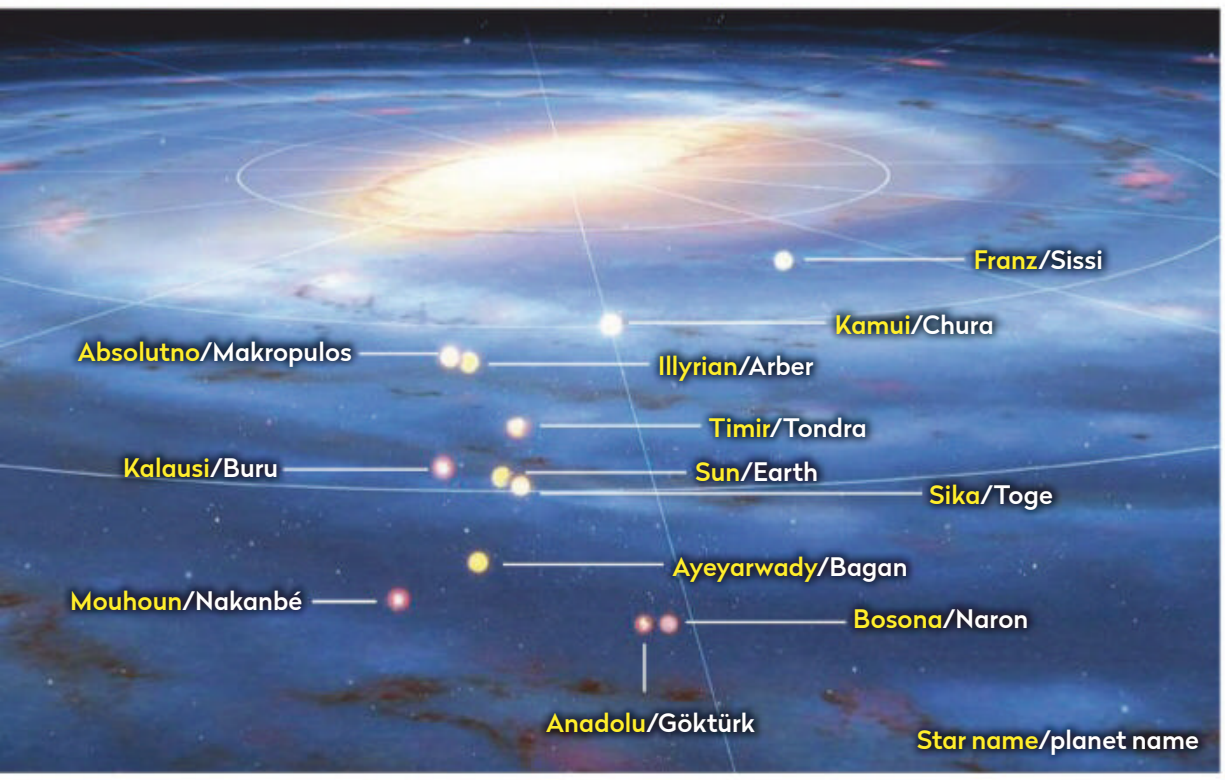
FIELD OF VIEW

A worldwide star-naming challenge

To celebrate its 100th anniversary the International Astronomical Union asked each country of the world to rename a host star and an orbiting exoplanet



◄ A selection of the newly named host stars and exoplanets located in our Galaxy

John Strachan is an astronomer researching the detection and characterisation of exoplanets at Queen Mary University of London, and was part of the IAU's NameExoWorlds steering committee

When an exoplanet is found, there's a convention for naming it. The name of the star gets a letter 'a' put after it and then each planet found in orbit around the star gets the next available lower-case letter in the alphabet. So for example, 55 Cancri b, is the name of the first exoplanet detected around 55 Cancri.

Although this is an easy way for astronomers to name and remember exoplanets in their research, it does have the downside of producing rather unremarkable names, especially when the star names are catalogue numbers, like HD189733 b. Exoplanets would be far easier to remember if they also had proper names, like the bright stars we're familiar with.

As part of its 100th anniversary, the International Astronomical Union (IAU) – the organisation which officially ratifies the names of bodies in space – decided to do just that. It launched the NameExoWorlds 2019 project, giving each country on Earth the opportunity to name a star and an exoplanet orbiting it.

As 2019 was also the United Nations International Year of Indigenous Languages, countries were encouraged to name their planetary systems using their native tongues. In addition, the names of the exoplanet and star had to have a theme linking them, which could be continued if additional exoplanets were found around the star in future. The stars were assigned to countries based on what was visible to them through a small telescope.

Astonomers in each country then set up their own national committees to run their campaigns. Here in the UK, we got the star WASP-13, around which a type of exoplanet known as a hot Jupiter was discovered in 2009. The national committee here chose to obtain proposals for names from young people across the country. All in all, 515 different naming themes were proposed.

The proposals were then shortlisted by the committee, and these 10 names were then put to a public vote to find a winner at the end of 2019. From this Cronk Y Berry Primary School on the Isle of Man emerged victorious. The schoolchildren chose names in Manx Gaelic: Gloas (pronounced glowas) for the star, which means 'shine'; and Cruinlagh (pronounced crunlack) for the exoplanet, which means 'orbit'.

Just a quick look at some of the winning names and themes from the 106 countries who took part shows their wonderful variety. The Cook Islands named their system after pearls: Poereva for the star, which is a large black pearl, and Pipitea for the planet, after a small white and gold pearl. Ethiopia named their system after words associated with their coffee ceremony. They named their star Buna, after the most commonly used word for coffee, and their planet Abol, after the first of the three traditional rounds of drinking coffee.

The winning names can be found at **www.nameexoworlds.iau.org**, along with links to all the national websites. I know the next time I come to study an exoplanet, I will look to see if it has been assigned a name from the NameExoWorlds project, and will include it along with the conventional name in any publications I write.

MARK GARLICK

BBC

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BBC Sky at Night MAGAZINE

APOLLO 13

Cast adrift en route to the Moon, the crew of Apollo 13 fought to stay alive. **Elizabeth Pearson** investigates what happened on board during that fateful mission

On the evening of 25 March 1970, the Saturn V that would soon carry Apollo 13 to the Moon cast a long shadow across launch pad 39A. Security guard Earl Paige was sitting in his car, about to drive off but as he turned the key, his car suddenly burst into flames.

The engine's heat had ignited a cloud of oxygen dumped from the Saturn V's fuel tanks. Paige was pulled from the fire unharmed, but this wasn't the last time an oxygen tank would cause problems for the ill-omened Apollo 13.

During pre-flight briefings, commander Jim Lovell waved off concerns that a mission numbered 'unlucky 13' was destined to suffer misfortune – to his Italian forefathers, 13 was an auspicious number. But the press was desperate for a new angle on the Apollo missions, which the public were already growing tired of.

The press got their dose of bad luck for the mission a few weeks before launch. Lovell's son had German measles, as did back-up lunar module pilot Charles Duke. An astronaut getting sick at the Moon would be a disaster, so NASA tested the crew to see who was immune. Lovell and lunar module pilot Fred Haise were. Command module pilot Ken Mattingly was not.

Mission Control were forced to split the crew – something they'd sworn never to do – and swapped Mattingly for back-up pilot Jack Swigert.

On 11 April, 13:13 Houston time, Apollo 13 set off for the Moon. Five and a half minutes into the flight, Lovell felt the rocket rattling more than it had done on his previous flight with Apollo 8. The central engine of the S-II stage's five thrusters had shut down early but the computer compensated. ▸

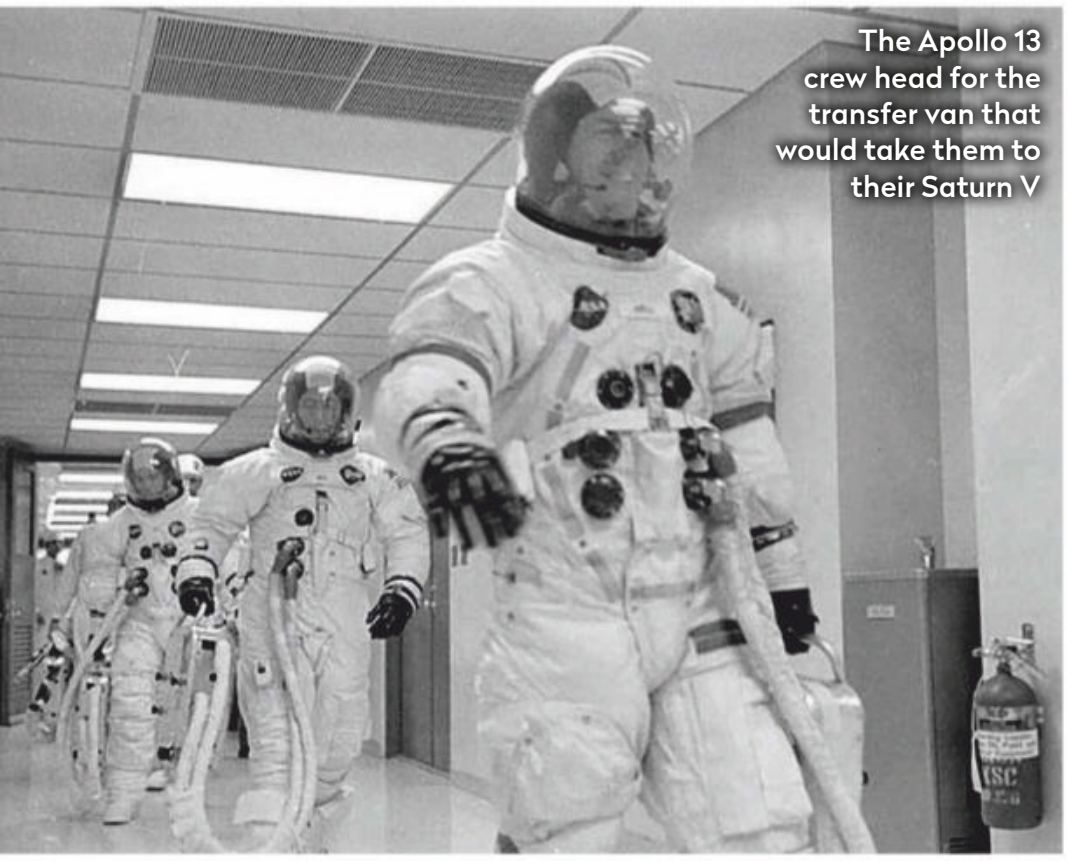
> "Houston, we've had a problem here."
> – Jim Lovell

MISSION BRIEF

Launch date: 11 April 1970
Launch location: Launch Complex 39A
Proposed landing location: Fra Mauro crater
Duration: 5 days, 22 hours, 54 minutes
Return date: 17 April 1970
Closest approach to the Moon: 254km
Firsts: aborted Apollo mission; use of lunar module as a lifeboat; furthest distance travelled from Earth (400,171 km)

NASA X 8

Apollo 13's Saturn V stands poised on the launch pad, backlit by the sunset



The Apollo 13 crew head for the transfer van that would take them to their Saturn V

▲ **Calm before the storm: all is routine in mission control, just hours before Apollo 13 reports a "problem"**

► Lovell breathed a sigh of relief. Every Apollo mission had at least one major crisis, so he was relieved Apollo 13's was out of the way early. From now on it should be smooth sailing.

It was 13 April, 9.05pm local time in Houston (14 April, 03:07 UT), 55 hours and 52 minutes into the mission and Apollo 13 was 322,000km from home. A handful of staff were left on duty at Mission Control, trading jokes about how dull the night shift was.

"13, we've got one more item for you when you get a chance," said Jack Lousma, acting as CAPCOM, the relay between Mission Control and the crew. "We'd like you to stir up your cryo tanks."

It was an innocuous order – the crew had already stirred the tanks four times during the mission. The crew followed it without thinking.

A bang, like a crack of thunder, rang through the spacecraft.

Disaster strikes

On the control panel, an error message lit up: 'Main bus B undervolt'. One of the two main electrical hubs had suffered an abrupt loss of power.

"Houston," Lovell radioed down to the ground, "we've had a problem."

Mission Control watched as the oxygen levels in Tank 2 plummed to zero. Slowly, Tank 1 began to follow suit. They were aware that these two tanks fed the three fuel cells onboard – without oxygen, there could be no power.

Hoping it might just be a glitch, Lovell glanced out the window.

"We are venting something out into the – into space," he said. It was their oxygen. The emergency was genuine.

Warnings lit up the control panel as system after system failed. They needed to stem the leak before their power was completely gone. With two of the fuel cells already dead and the other dying, Mission Control chose a drastic course of action.

"We want you to close the REAC valve on fuel cell 3. You copy?" said Mission Control.

"...You want me to shut the REAC valve on fuel cell 3?" Haise queried. "Did I hear you right?"

Closing the valve would turn off the fuel cell. They would not be able to restart it. Whatever happened afterwards, the crew of Apollo 13 would definitely not land on the Moon.

"That's affirmative."

Haise followed the order but the oxygen in Tank 1 continued to fall. Mission Control feared Tank 2 had ruptured, nicking Tank 1 to create a slow but unstoppable leak. They needed to bring the crew home. Fast.

First choice was using the service module's main engine to perform a U-turn, returning the crew to Earth within two days, but there wasn't enough power. The only other option was to somehow nudge the spacecraft so that it swung around the Moon, returning to Earth five days later.

With the direness of the situation setting in, both Mission Control and crew settled on a procedure intended for the grimmest of emergencies – using the lunar module, Aquarius, as a lifeboat.

With less than 15 minutes before the command module, Odyssey, ran out of power, Swigert had to

"The spacecraft is in real good shape as far as we're concerned, Jim. We're bored to tears down here"
– CAPCOM Joe Kerwin, 9 hours before the explosion

NASA X 8

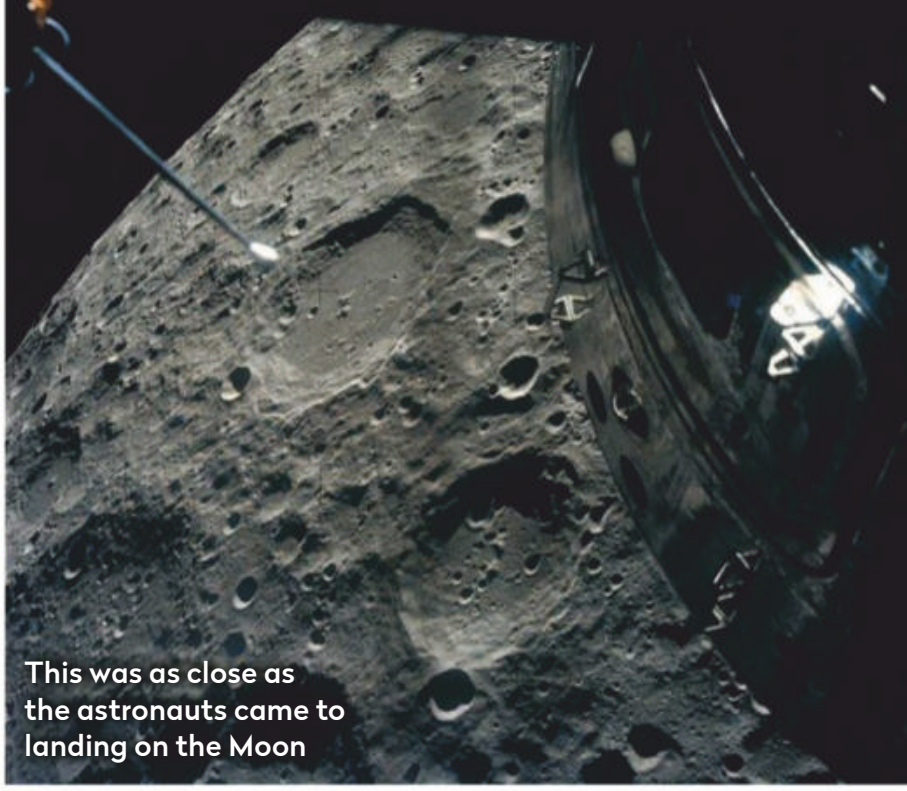
Meet the astronauts

Commander: James 'Jim' Lovell
Lovell was a spaceflight veteran, having flown in Gemini 7, Gemini 12 and Apollo 8. During the latter, he trialled a method of navigation using Earth's terminator which he used again during the Apollo 13 disaster. Like all the Apollo 13 crew, he never flew in space again.

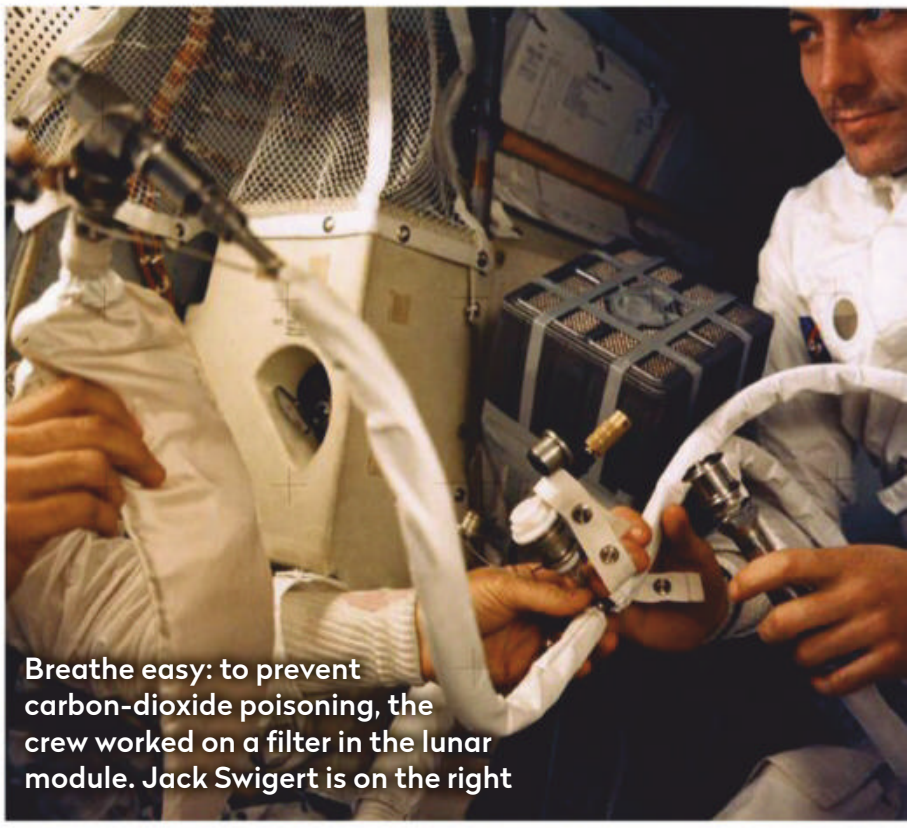
Lunar module pilot: Fred Haise
Before joining NASA, Haise served in the Marines and the Air Force. He was meant to fly on Apollo 19 but this was later cancelled, and he moved into development of the new Space Shuttle. He went on to work for Grumman Aerospace Corporation, the company which built the lunar modules, including Aquarius.

Command module pilot: Jack Swigert
Swigert was in the Air Force and worked as a test pilot before joining NASA in 1966. He was one of the few astronauts who requested to be a command module pilot rather than walk on the Moon. He later entered politics and was elected to Congress but died before being sworn in.

Original command module pilot: Ken Mattingly
A former naval officer, Mattingly had been with NASA since 1966. During the Apollo 13 disaster, he ran simulations to help bring his crewmates home. He eventually reached the Moon with Apollo 16 in 1972 and flew two Shuttle missions. He still hasn't contracted German measles.



This was as close as the astronauts came to landing on the Moon



Breathe easy: to prevent carbon-dioxide poisoning, the crew worked on a filter in the lunar module. Jack Swigert is on the right

turn off every system possible, while Haise and Lowell – the lunar module crew – were tasked with powering up Aquarius. With one radio link to the ground, orders volleyed back and forth between the two teams, confusing the astronauts over which instructions were meant for who.

"13, You're both talking at once," Lousma reprimanded; too much haste could be as deadly as too little. "One at a time please."

Drastic measures

Methodically, Swigert shut down Odyssey until it was quiet as a tomb. The command module pilot left his charge behind and crossed over into Aquarius, a vehicle he was never meant to enter, on a mission he was never meant to fly, with colleagues he was never meant to work with. From then on, his fate was in his crewmate's hands.

At 61 hours and 30 minutes into the mission, Lovell and Haise fired the lunar module's engine to send them around the Moon, and then prepared for the main burn that would speed their way home. Meanwhile, the Moon loomed into view.

"Well," Lovell sighed. "I'm afraid this is going to be the last lunar mission for a long time."

Despite their exhaustion, both crew and Mission Control worked through the mission with a calm focus, though the media painted a very different picture. As camera crews camped out on the lawns of the astronaut's homes, reporters painted Mission Control as a riot of chaos and fear, transforming every breath into a life-or-death struggle. Lunar missions didn't seem so boring now.

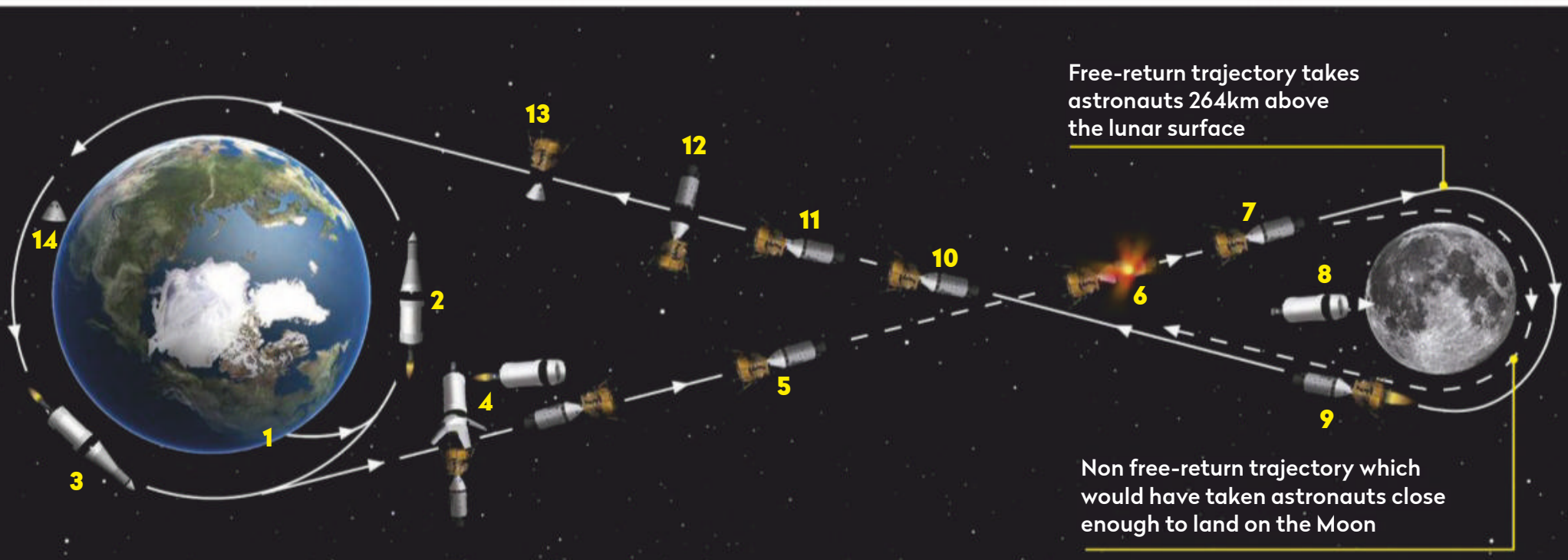
When the Apollo 13 crew emerged from behind the Moon, they carried out their final burn. The lunar module's engine was only designed for a single use, and no one knew how it would fare during this second firing. To the crew's relief, it lasted all four minutes and 24 seconds required.

The crew were finally heading home: splashdown would be in three days. They just needed to survive that long.

The most immediate concern was keeping the astronauts breathing. The lunar module's oxygen reserves were more than enough for the crew, but when Odyssey shut down, so did its carbon dioxide filters. Though Aquarius had its own, they were only meant to keep two people alive. Now they were supporting three. The deficit would soon cause the gas to reach toxic levels.

Odyssey had spare filters – but they were square. The lunar module took round ones. After a day of planning, engineers on the ground walked the astronauts through the process of making them fit using the assortment of items available onboard, and the crew could breathe easy again. ▸

▼ After the accident the Apollo 13 flightpath had to change in order to get the crew safely back to Earth



1. LIFTOFF: 11 April, 19:13 UT

2. S-IVB third stage fired on collision course with the Moon

3. Manoeuvre into lunar trajectory

4. Docking with lunar module

5. 13 April, 01:54 UT: Apollo changes trajectory to prepare for Moon landing

6. EXPLOSION: 14 April, 03:07 UT, 322,000km from Earth

7. 14 April, 08:42 UT: Apollo changes back to Earth-bound trajectory

8. S-IVB impacts on the Moon

9. 15 April, 02:41 UT, 4 and a half minute burn by lunar module DPS (descent propulsion system)

10. 16 April, 04:31 UT: mid-course correction

11. 2nd mid-course correction

12. 17 April, 13:14 UT: service module jettisoned

13. 17 April, 16:43 UT: crew transfer to command module. Jettison of the lunar module 'lifeboat'

14. SPLASHDOWN: 17 April, 18:07 UT

ILLUSTRATION BY PAUL WOOTTON (BASED ON NASA DATA) NASA X 3

▸ The next problem was water. Odyssey was cooled by the liquid but its tanks were meant to be topped off by the waste water produced by the now defunct fuel cells. The crew limited their drinking to conserve as much as possible, eventually being rationed to just 200ml a day.

Elsewhere there was too much water, as the moisture in the astronauts' breath and sweat built up in the air. The heaters were set to a minimum to conserve power and the temperature was just 9°C, meaning water condensed onto everything – including the crew.

Damp and cold, the astronauts took turns trying to sleep. While the one crewman on watch was taking pills to stay awake, the other two were shivering in their couches, unable to sleep.

Only Haise was having no problem staying warm. The combination of dehydration and exhaustion had led to a urinary tract infection and he was now running a fever.

Long journey home

Throughout the long trip home, the crew siphoned power from the lunar module to Odyssey's batteries until it had enough power to operate the descent hardware the crew needed to survive splashdown. Over 135 hours after leaving Earth, the crew were almost home again.

Only the command module could survive re-entry, so the crew jettisoned the service module which carried the problematic oxygen tanks. As it floated away, Lovell pressed his face to the window to see what had happened during the explosion. "There's one whole side of that spacecraft missing," he said, seeing the tank had not just ruptured, but exploded. "It's really a mess."


Jim Lovell tried to sleep during the tense return journey to Earth

The next vehicle was harder to say goodbye to – the lunar module which had been their salvation.

"Farewell, Aquarius," said the voice of CAPCOM as it floated away, "And we thank you."

As the crew prepared to land, millions of people on

> "We are in the shadow of the Moon now... Man, look at all those stars." – Jim Lovell

MISSION TIMELINE

11 April 19:13*
Apollo 13 launches

14 April 03:06
Tank 2 stirred, explodes a minute later

14 April 03:08
"Houston, we've had a problem here"

14 April 04:37
Mission Control and the crew consider Aquarius as a lifeboat

14 April 05:13
Fred Haise shuts down last fuel cell – Moon landing now impossible

14 April 05:23
Odyssey's systems turned off to conserve power

14 April 08:42
Mid-course correction nudges Apollo 13 into return trajectory

15 April 00:21
Apollo 13 disappears behind the Moon, before emerging 25 minutes later

15 April 13:22
Crew fabricate a carbon dioxide filter

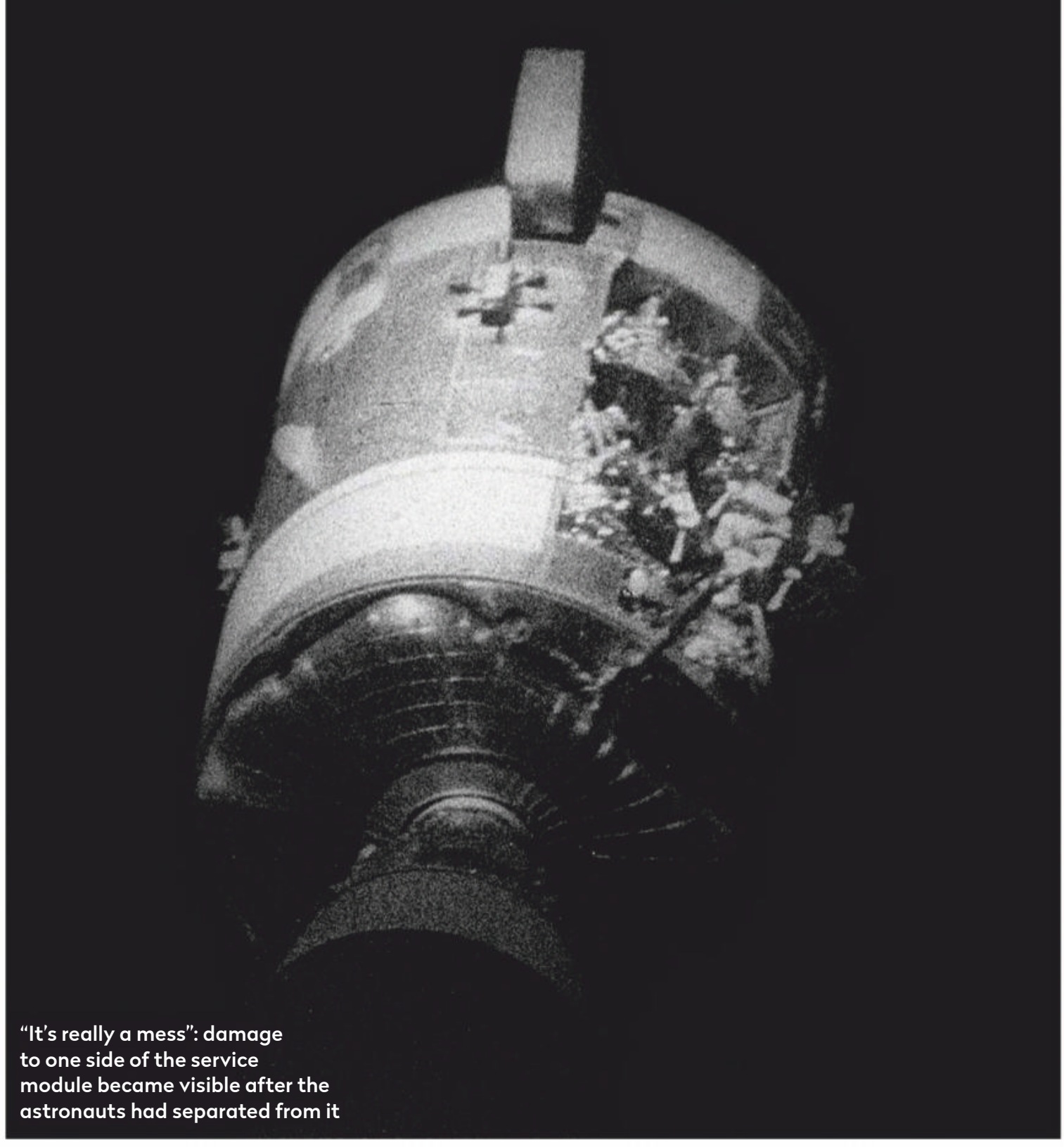
16 April 11:33
Power transfer to emergency batteries begins

17 April 13:14
Service module separates, and the crew photographs the damage

17 April 15:23
Odyssey is powered back up in preparation for the descent

17 April 18:07
Splashdown

*All times are UT



"It's really a mess": damage to one side of the service module became visible after the astronauts had separated from it

Home at last: a worldwide audience of millions watched the astronauts return

Earth gathered around televisions and radios, willing them a safe return while the news bandied fears that the heatshield had been damaged in the accident. After running a marathon rescue, would Apollo 13 expire just yards from the finish line?

As the crew hit the atmosphere, the heatshield held. At 18:07 UT, 142 hours and 54 minutes after launching, Apollo 13 arrived home. Safe.

The recovery ship USS *Iwo Jima* rushed the crew to Honolulu where their families awaited. While they recovered from their ordeal, NASA hunted down the accident's cause. The culprit: a single switch meant to stop the oxygen tanks overheating had failed three weeks before the flight. Temperatures in Tank 2 had risen to over 500°C, damaging its wiring. When the crew stirred the tank it had sparked, igniting the oxygen. One minor component in a machine made of millions had almost cost the Apollo 13 crew their lives.

But it was the work of many which brought those three lost souls home. While the press lauded the courage of the crew, the astronauts pointed out they'd never been alone – 100,000 people on the ground had helped them.

Turn the page to read what was happening at Mission Control during the rescue ▸

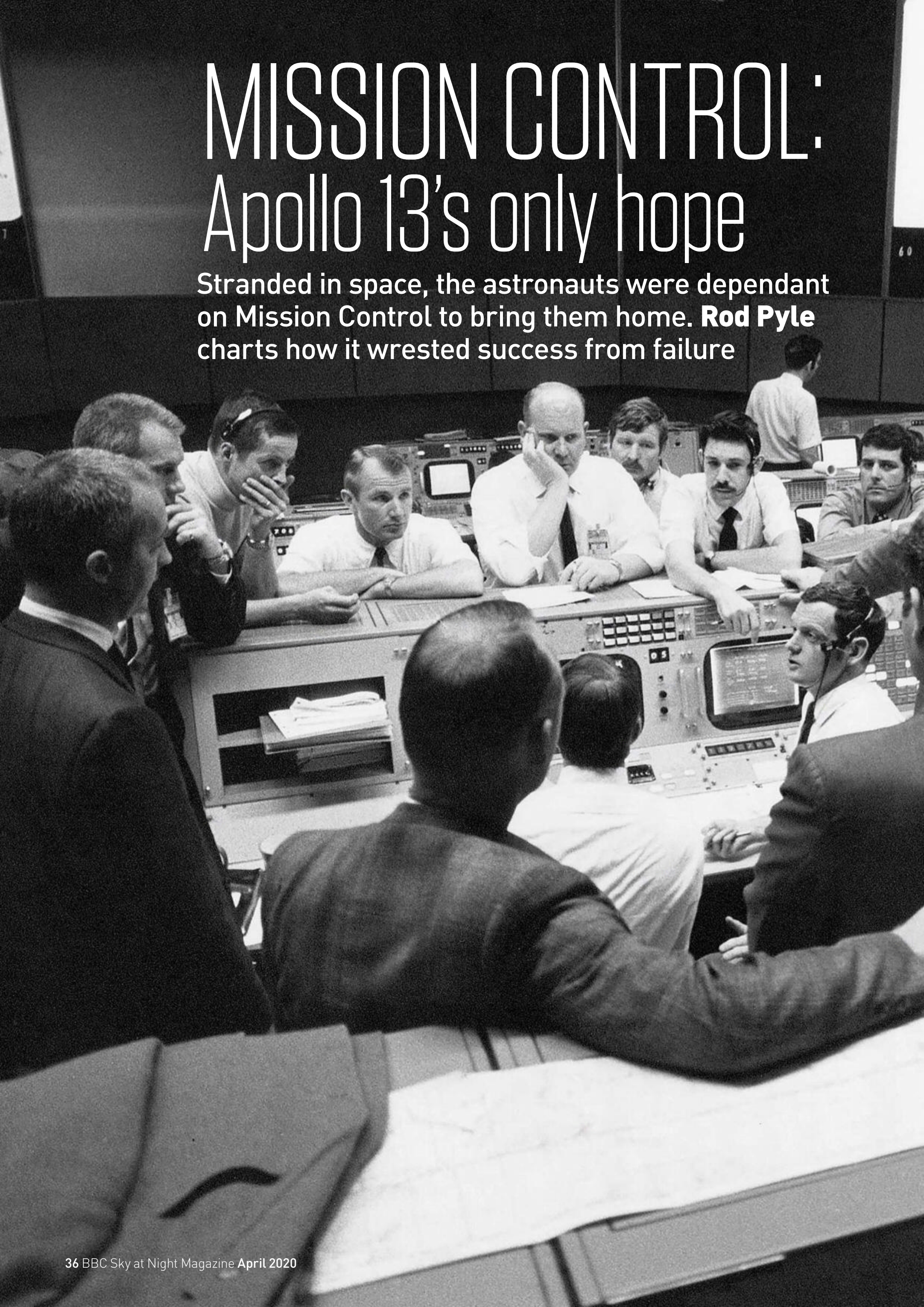
BBC WORLD SERVICE

The BBC podcast *13 Minutes to the Moon* is taking an in-depth look at the Apollo 13 mission, including interviews with astronauts Jim Lovell and Fred Haise. Download it from 9 March on **bbcworldservice.com**

Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University

MISSION CONTROL: Apollo 13's only hope

Stranded in space, the astronauts were dependant on Mission Control to bring them home. **Rod Pyle** charts how it wrested success from failure



All hands on deck: Mission Control's flight controllers confer during the tense final 24 hours of the Apollo 13 mission

NASA

Amidst the funereal atmosphere at NASA's Mission Control Center in the days following the Apollo 1 fire in 1967, flight director Gene Kranz gathered his flight controllers and associated personnel in Building 30 to talk to them about the fire. His words, though not recorded, have since been memorialised as "The Kranz Dictum".

In part, he said: "Spaceflight will never tolerate carelessness, incapacity, and neglect... From this day forward, Flight Control will be known by two words: 'Tough' and 'Competent'. Tough means we are forever accountable for what we do or what we fail to do. We will never again compromise our responsibilities. Every time we walk into Mission Control, we will know what we stand for. Competent means we will never take anything for granted. We will never be found short in our knowledge and in our skills. Mission Control will be perfect." And he meant it.

On 14 April 1970 at 03:08 UT the personnel of Mission Control were about to earn their 'Tough' and 'Competent' stripes once again. Just over two days into the mission, Jack Swigert radioed down from the Apollo 13 command module Odyssey, "Okay, Houston, we've had a problem here." The CAPCOM (capsule communicator), fellow astronaut Jack Lousma, asked him to repeat his message. Then Jim Lovell, the commander of the mission, said the words that still send a chill down the spine some 50 years later: "Houston, we've had a problem..."

State of emergency

Kranz was just handing off to the next shift of Mission Control personnel, led by fellow flight director Glynn Lunney, when the call came down. As Kranz later wrote, "In the [Mission Control Center], you can't see, smell, or touch a crisis except through the telemetry and the crew's voice reports. But you can feel some instinct kicking in when something very wrong is going on." Something very wrong had just occurred.

After a muffled bang, two of the three fuel cells that powered the command ►

Keeping watch: astronauts and flight controllers monitor Apollo 13's progress. Seated (on the right) are astronauts Alan Shepard and Edgar Mitchell

NASA X 3

▸ module had shut down, and the interior of the command module was awash with the blaring of the master alarm and warning lights blazing across the console. What was not yet clear was that one of two large oxygen tanks in the service module – which were critical not just for life support, but also for power via the fuel cells — had exploded due to a spark from a faulty thermostat inside. To make matters worse, the piping from the second tank had been damaged. In less than three hours, both tanks would be empty, the oxygen supply depleted, and the command module dead and cold as a meat freezer.

It took about 15 minutes for Mission Control to determine the scope of what was now an in-flight emergency. The strange numeric readouts that the flight controllers were seeing on their screens had coalesced into an understandable set of problems, and those controllers – whose average age was just 27 – were now working in tight coordination to get their crew home. They were backed by dozens of other experts in the 'back rooms' of Building 30 at the Johnson Space Center, and by engineers and experts from the various contractors all over the country.

High stakes

The spacecraft was about 300,000km from Earth, and just 72,000km from the Moon. Decisions would have to be made quickly. Fortunately, Mission Control already had a plan in hand, informally referred to as the 'lunar module lifeboat' plan.

Kranz's White Team (each of the three shifts were colour-coded) gathered up all the data available to them, then turned over the control room to Lunney's

It took 15 minutes for Mission Control to determine the scope of what was now an in-flight emergency

Black Team. "I wanted to get the White Team off-line, get them together in a quiet corner, nail down the cause, and then start on a plan to rescue the crew," he later said.

At this point, they had two options: a direct abort, which would involve firing up the main engine on the service module and performing a long burn to blunt their velocity and send them back to Earth without flying past the Moon, or allowing the spacecraft to sling past the Moon – an option called 'free return' – to hurtle Earthward with the assist of lunar gravity and navigation provided by the lunar module's smaller descent engine.

While both options were considered, there were concerns about power and worries that the service module's main engine might have been damaged by the explosion and could in turn blow up if ignited. A direct abort would also necessitate jettisoning the lunar module, an option few were comfortable with. The best option, it seemed, was to allow the spacecraft to loop the Moon. But that would take two additional days in space and oxygen, water (needed for drinking and cooling the hot 1960s electronics), and power (the lunar module ran off

batteries) were in short supply. At least one of these commodities would come up 36 hours short.

Kranz's White Team relocated to another room to discuss options and find solutions. Controllers carried reams of data printouts, cigarette smoke filled the air, and dozens of voices competed for attention. Kranz commanded the room to silence and asked three engineers to come front and centre — Arnie Aldrich, Bill Peters, and John Aaron.

Rising to the challenge

Kranz declared that the White Team was now offline — they would return to Mission Control only for critical mission events. He assigned Aldrich to build the rescue mission timeline, Peters to oversee the use of the lunar module as a lifeboat, and Aaron to budget life support, water and power. "Whatever any of these three ask of you, you will do," he told the room.

He then added, "When you leave this room you will pass no uncertainty to our people. They must become believers if we are to succeed." Strong leadership and a sense of inevitable victory were as critical as the numbers now. "Flight Control will never lose an American in space," he added with a steely glare.

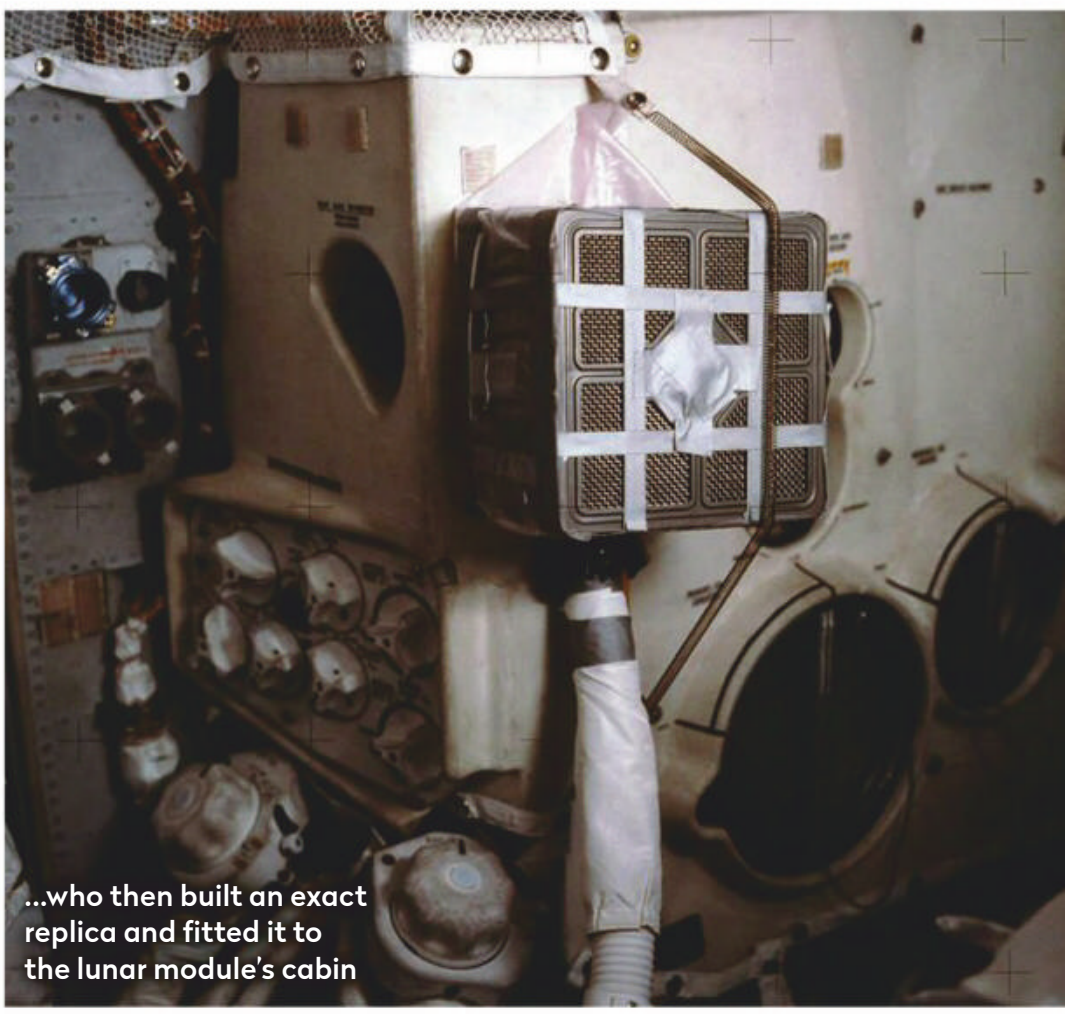
By the time Kranz returned to Mission Control, he learned that they would have to use the rapidly depleting lunar module batteries keep the power-hungry guidance computer running until their mid-course burn many hours away. John Aaron's challenge was now a near-impossibility, and he would not return to his console until re-entry days later.

A day after the explosion and two hours after passing the Moon, the crew performed the burn that would put them on a proper return trajectory for Earth. Success was by no means a foregone conclusion — the combined lunar module/command service module 'stack' was never designed to be manoeuvred by the lunar module's main engine. But, as with most contingencies, it had been planned for, simulated and even tested on Apollo 9.

But with one problem solved, another took its place almost immediately. The carbon dioxide levels inside the spacecraft were rising to toxic levels. The CO_2 scrubbers on the lunar module were depleted, and the crew would soon need to use the scrubbers from the command module. The lunar module's filters were round, however, and those on the command module were square — they were not interchangeable. Fortunately, there had been a simulation prior to Apollo 8 that involved a similar problem, and fellow astronaut Joe Kerwin, who was familiar with the procedure, quickly brought everyone up to speed. The crew would fabricate an adaptor using a sock, plastic bags, a sheet of cardboard and duct tape. The fix worked and CO_2 levels gradually fell as the adapted scrubber did its work.

There were also astronauts in the command module simulator testing re-entry procedures for the ▸

▼ Time to improvise: NASA's Deke Slayton examines the makeshift adaptor to reduce CO_2 levels, before instructions are relayed to the Apollo 13 crew...



...who then built an exact replica and fitted it to the lunar module's cabin

Inside Mission Control

At the helm: flight director Gene Kranz surveys the monitors in Mission Control

Mission Control at the Johnson Space Center in Houston, Texas, is where all of NASA's human spaceflights have been run since the Gemini Program. The control rooms are called Mission Operation Control Rooms (MOCR) and the Apollo-era MOCR is now a national landmark and was recently restored to its original condition.

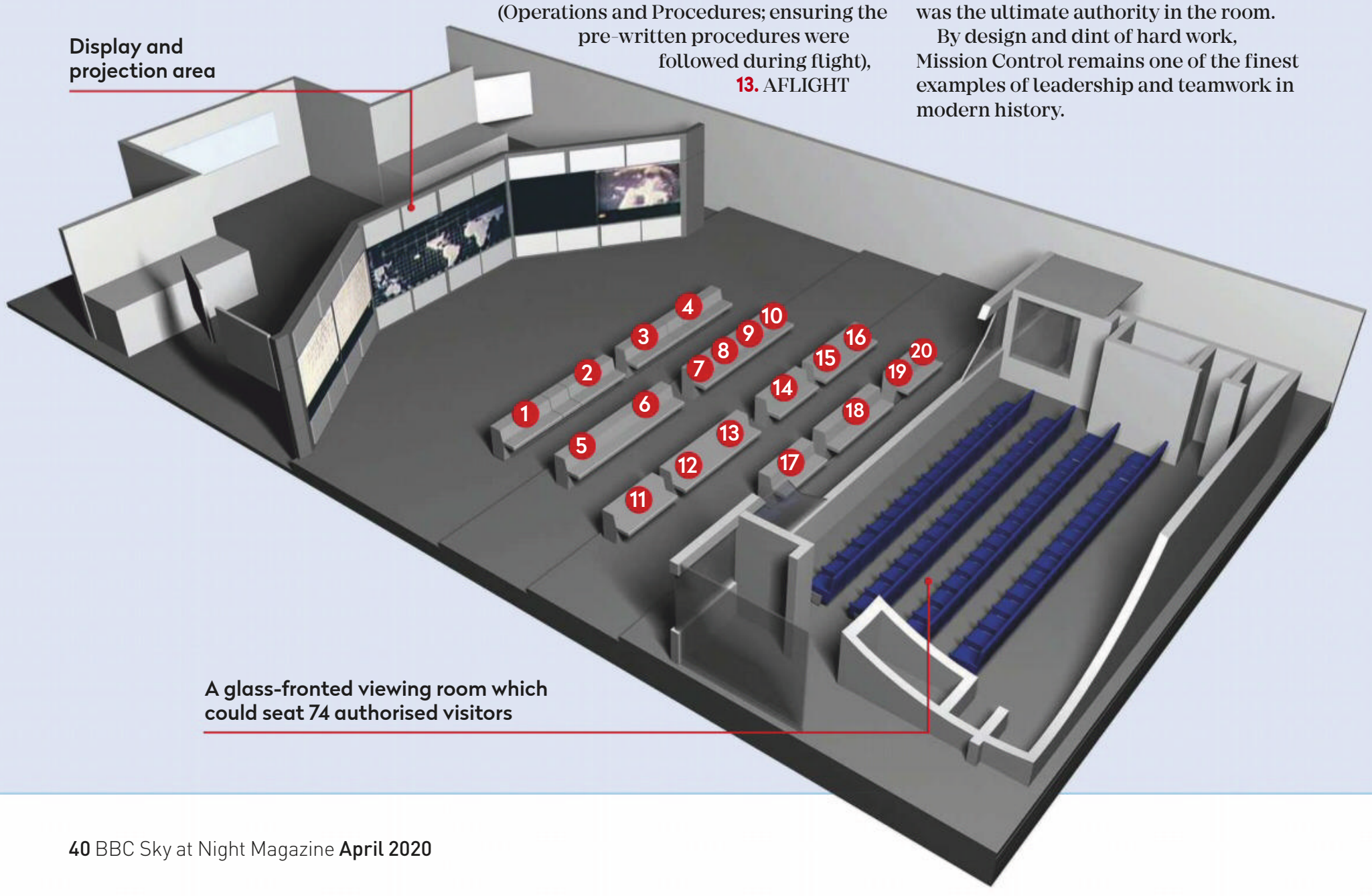
Mission Control 2, the one used for the Gemini, Apollo and early Shuttle programmes, is arranged in four rows of interconnected consoles that reach across the room with large rear-projection screens at the front. The front row consisted of stations called **1.** Booster (Booster systems engineer; monitoring rocket systems), **2.** RETRO (Retrofire Officer; re-entry procedures and leaving orbits), **3.** FDO (Flight Dynamics Officer; trajectories and aborts), and **4.** GUIDO (Guidance Officer; flight computers, navigation and guidance). Some stations were staffed by one person, and others had multiple controllers.

The second row consisted of **5.** Surgeon (the doctor who monitored the astronauts' health), **6.** CAPCOM (Capsule Communicator; the astronaut who was the sole point of contact with the flight crew), **7.** EECOM (Electric, Environmental and Consumables Manager; fuel cells, cooling systems, electrical and cabin pressure systems), **8.** GNC (Guidance, Navigation and Control engineer; guidance and trajectory flight hardware, as well as manoeuvring systems), **9.** TELMU (Telemetry, Electrical and EVA Mobility Unit; lunar module systems and spacesuits), and **10.** CONTROL (responsible for the lunar module's electrical and propulsion systems). TELMU was quite busy during Apollo 13 when the lunar module became a lifeboat for the crew.

On the third row was **11.** INCO (Instrumentation and Communications Officer; for voice, telemetry and video communications systems), **12.** O&P (Operations and Procedures; ensuring the pre-written procedures were followed during flight), **13.** AFLIGHT (Assistant Flight director), **14.** FLIGHT (Flight director; in charge of the room and the mission), **15.** FAO (Flight Activities Officer; overseeing all crew activities), and **16.** NETWORK (Network controller; to oversee the ground network of communication stations – not used during the Apollo 13 mission).

The fourth row contained the **17.** PAO (Public Affairs Officer), **18.** DFO (Director of Flight Operations; linked Mission Control and Johnson Space Center management), **19.** HQ (linked Mission Control to NASA headquarters), and **20.** DOD (Department of Defense; linked Mission Control and recovery forces at sea). This fourth and final row was reserved for NASA management to observe during the flight, but the flight director was the ultimate authority in the room.

By design and dint of hard work, Mission Control remains one of the finest examples of leadership and teamwork in modern history.



▲ **Success story: flight director Gene Kranz (second from left) celebrates after Apollo 13's splashdown on 17 April 1970**

▼ **Welcome return: Apollo 13's crew (from left) Fred Haise, Jim Lovell and Jack Swigert are back safely**

► stricken spacecraft – it would have to be revived from the dead to complete the trip home. This would be touch-and-go, as the crew was dehydrated, sleep deprived and they were enduring near-freezing temperatures – all conditions which could conspire to trip up critical manoeuvres. Their list of procedures was 39 pages long, all 400 steps would have to go right for success. Mission Control, and the many people and organisations that backed them, worked tirelessly to make it as foolproof as possible. As Kranz had predicted after Apollo 1, Mission Control would indeed be perfect.

Final stretch

On 17 April, in the dead of night – not that day or night meant much to any of the sleep-deprived controllers now – Kranz's White Team took to their consoles for the final stretch. Most of the White Team members had been working almost continuously for the past 80 hours with short naps to take the edge off. Caffeine and tobacco held them together as the last of the long list of procedures were read up to the exhausted crew by the CAPCOM, who was surrounded by three other astronauts to make sure there were no errors.

Then the service module was ejected, and the crew saw that the damage stretched from its top down across the rocket nozzle. Kranz, and many others, were doubly glad that they had not elected to attempt the direct abort — the service module's engine might well have exploded.

Kranz polled his team and gave the order: "Go for entry." Not that there were many alternatives. Apollo 13 was headed into the atmosphere like a freight train going 40,000 km/h. The room grew mostly still until Swigert radioed down, "I know all of us here want to thank all you guys down there for the very fine job you did." More than one controller was misty-eyed.

Then the crew went silent, as Apollo 13 descended into blackout, the period in which radio communications are obliterated by the fury of re-entry. As Kranz later put it, "Everything was now irreversible." All Mission Control, and the millions across the nation and the planet who were listening in, could do now was to wait.

Shortly after the countdown timer passed 00:00:00, CAPCOM Joe Kerwin attempted to contact the crew: "Odyssey, Houston. Standing by." Nothing but static answered him. One minute passed, then another 30 seconds ticked by. Increasingly anxious, Kranz inquired if the clocks were accurate... they were. He slammed his fist on his console, drawing surprised looks from tense controllers.

Finally, after more attempts at contact, they heard "Okay, Joe," from Swigert. Cheers erupted as three parachutes blossomed into view. In Mission Control and the viewing room, in the support rooms, at the many contractors across the nation, and in public spaces from New York's Grand Central Station to countless places across the world, people clapped, cheered and exalted in the moment. The emergency of Apollo 13 was over – human ingenuity and spirit had triumphed in space once again.

Completely spent, Kranz slumped in his government-issue chair. The hard-as-nails flight director loosened his grip for a moment and cried. He tried to hold it in, but it was for naught. Days of stress, anxiety and concern spilled out in a warm rush of gratitude.

"Our crew was home," he recalled. "We – crew, contractors, controllers – had done the impossible. The human factor had carried the day."

Rod Pyle is the author of 15 space books and editor-in-chief of *Ad Astra* magazine for the US National Space Society

NASA X 3, ILLUSTRATION BY PAUL WOOTTON

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BBC Sky at Night MAGAZINE

The Sky Guide

APRIL 2020

VENUS AND THE PLEAIDES

Look west to see brilliant Venus passing in front of the Pleiades open cluster

GANYMEDE'S SHADOW

Observe a daytime transit of Jupiter's moon

PEAK PERFORMANCE

A new Moon allows a clear view of the Lyrid meteor shower

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- Lunar occultation of the Lagoon Nebula, M8
- Asteroid 3 Juno, a larger body of the asteroid belt
- Get to know the lunar crater Blancanus

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

APRIL HIGHLIGHTS

Your guide to the night sky this month

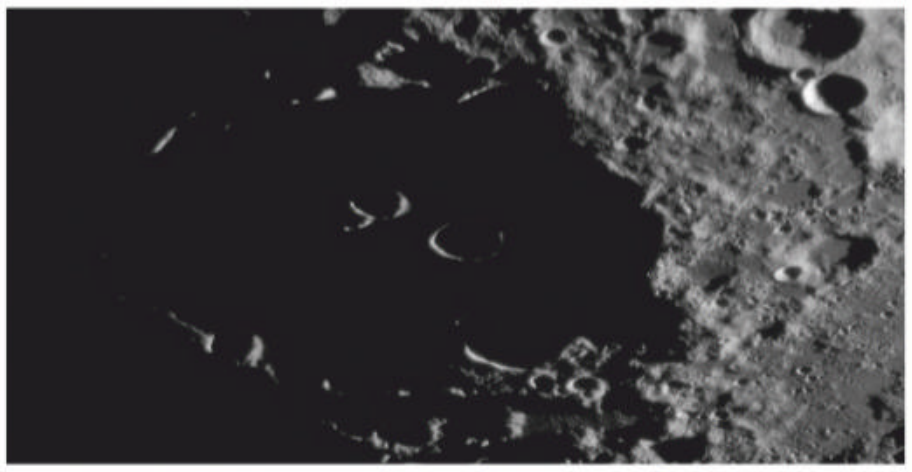
Wednesday 1

Mag. +0.8 Mars sits 1° to the south of the ringed planet Saturn this morning. Off-white Saturn shines at mag. +0.9, a similar brightness to orange Mars.

Thursday ▶ 2

The crater Clavius will be bathed in dark shadow in the early hours save for two crater rims inside it which form the clair-obscur effect known as the Eyes of Clavius.

This evening, asteroid 3 Juno reaches opposition in Virgo, shining at mag. +9.5.



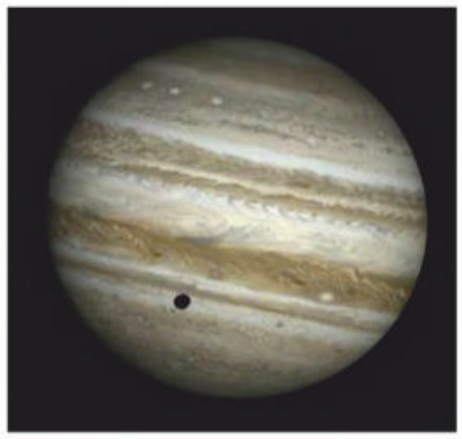
Saturday 4

A challenging target for astrophotography, the bright planet Jupiter will appear 45 arcminutes from Pluto this morning. Jupiter shines at mag. –2.0, Pluto at mag. +14.4. At this time Jupiter will be 3.6 million times brighter than Pluto.

Sunday 5

Peak of the weak meteor shower known as the Kappa Serpentids. The peak ZHR (Zenithal Hourly Rate) for this shower is just four meteors per hour.

This evening the Moon appears at perigee, its closest point to Earth, at 19:08 BST (18:08 UT).



◀ Wednesday 8

This morning's full Moon, 03:35 BST (02:35 UT) occurs close to perigee, a 'supermoon', and will appear larger than an average full Moon.

Ganymede's shadow is on Jupiter's central meridian at 05:30 BST.

◀ Monday 13

The rising 69%-lit waning gibbous Moon will be occulting the Lagoon Nebula, M8. The Moon clears the nebula at 03:30 BST (02:30 UT). Although the nebula won't be visible, it may be possible to see some of the embedded cluster stars under occultation.

Wednesday 15

Early risers can see a 48%-lit waning crescent Moon in a triangle with Jupiter and Saturn at 04:30 BST (03:30 UT).

At 09:30 BST (08:30 UT) Ganymede's shadow is on Jupiter's central meridian.

Wednesday ▶ 22

The annual Lyrid meteor shower reaches its peak this evening. It has a peak ZHR of 18 meteors per hour but can show variable rates up to 90 meteors per hour. Conditions this year are perfect as there's a new Moon on 23 April at 03:26 BST (02:36 UT).

Thursday 23

The Moon is new today, making this a great time to try this month's *Deep-Sky Tour* on page 56. This month we're looking at galaxies of all shapes and sizes near the bottom of the Bowl of Virgo.

Saturday 25

The blazing planet Venus reaches 30% phase today. Venus can currently be seen in the evening sky over towards the west after sunset, shining away at mag. –4.5.

Family stargazing

As Venus is such a prominent object in the evening sky at the moment it's easy to locate through a small telescope. Once the Sun has set, invite your young observers to find it using a telescope fitted with a low-power eyepiece. Once found, try increasing the magnification and ask them to record what they see. Repeat this over several nights spread over the course of the month. Venus is growing and showing as a beautiful crescent. Visually the view is quite beautiful, a close second to seeing the rings around Saturn in terms of wow factor.
www.bbc.co.uk/cbeebies/shows/stargazing

Monday 27

This evening the 20%-lit waxing crescent Moon lies 1.4° to the south of the fifth magnitude open cluster M35 in Gemini.

PETE LAWRENCE X 7

Friday 3

The planet Venus will cross the Pleiades open cluster this evening. Turn to page 46 for more information. Venus is currently shining at mag. –4.3.

Thursday 16

As the 37%-lit waning crescent Moon rises around 05:00 BST (04:00 UT) this morning, look out for mag. +0.6 Mars, 2.9° to its north.

Friday 17

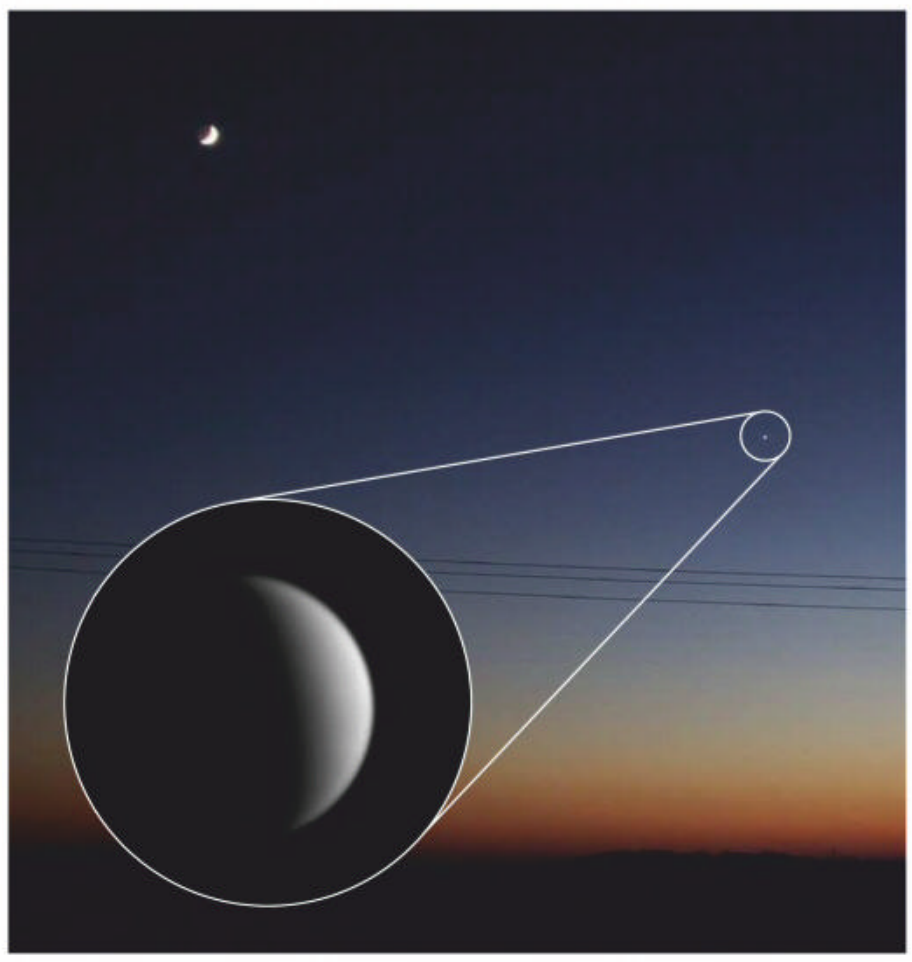
This evening it's the turn of the weak Alpha Virginids meteor shower to reach its peak. The ZHR for this shower is just five meteors per hour. These meteors have a slow entry speed of around 20km/s.

Saturday 18

A lack of a Moon in this evening's sky makes this an excellent time to try for our challenge on page 55. This month we're asking you to take a photo of the shadow cast by the planet Venus.

Sunday ▶ 26

Mag. –4.4 Venus appears 6.5° from this evening's 12%-lit crescent Moon. A stirring visual sight, this is a must take shot if you're into astrophotography.



◀ Thursday 30

The Moon reaches first quarter phase this evening, the second first quarter Moon of the month.

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE

The three top sights to observe or image this month

DON'T MISS

Venus against the PLEIADES

BEST TIME TO SEE: All month.
Closest approach 2–5 April

Beautiful Venus has dominated the western twilight sky for many weeks and is now a familiar sight after sunset. The planet is very bright, shining at mag. –4.3 on 1 April, brightening to –4.4 by the end of the month. It's favourably positioned for UK viewing, staying above the horizon for nearly five hours on 1 April and 4.3 hours on the 30th. Venus is easy to spot as soon as the Sun sets but this extended period above the horizon means that its visibility improves because there is time for the background sky to fully darken.

At the start of April, Venus appears against an astronomically dark sky for 2.7 hours. By the end of the month, the expanding period of daylight erodes this time to 1.7 hours. One issue when waiting for Venus to appear against a truly dark sky is its lower altitude.

At the month's start, Venus's appearance is further enhanced by virtue of its position against the background stars. On 1 April, it lies 2° west-southwest of mag. +2.8 Alcyone (Eta (η) Tauri), the brightest star in the Pleiades open cluster. This apparent separation is small enough to provide an excellent opportunity for astrophotography and heralds an even more spectacular conjunction between the cluster and planet over the next couple of days.

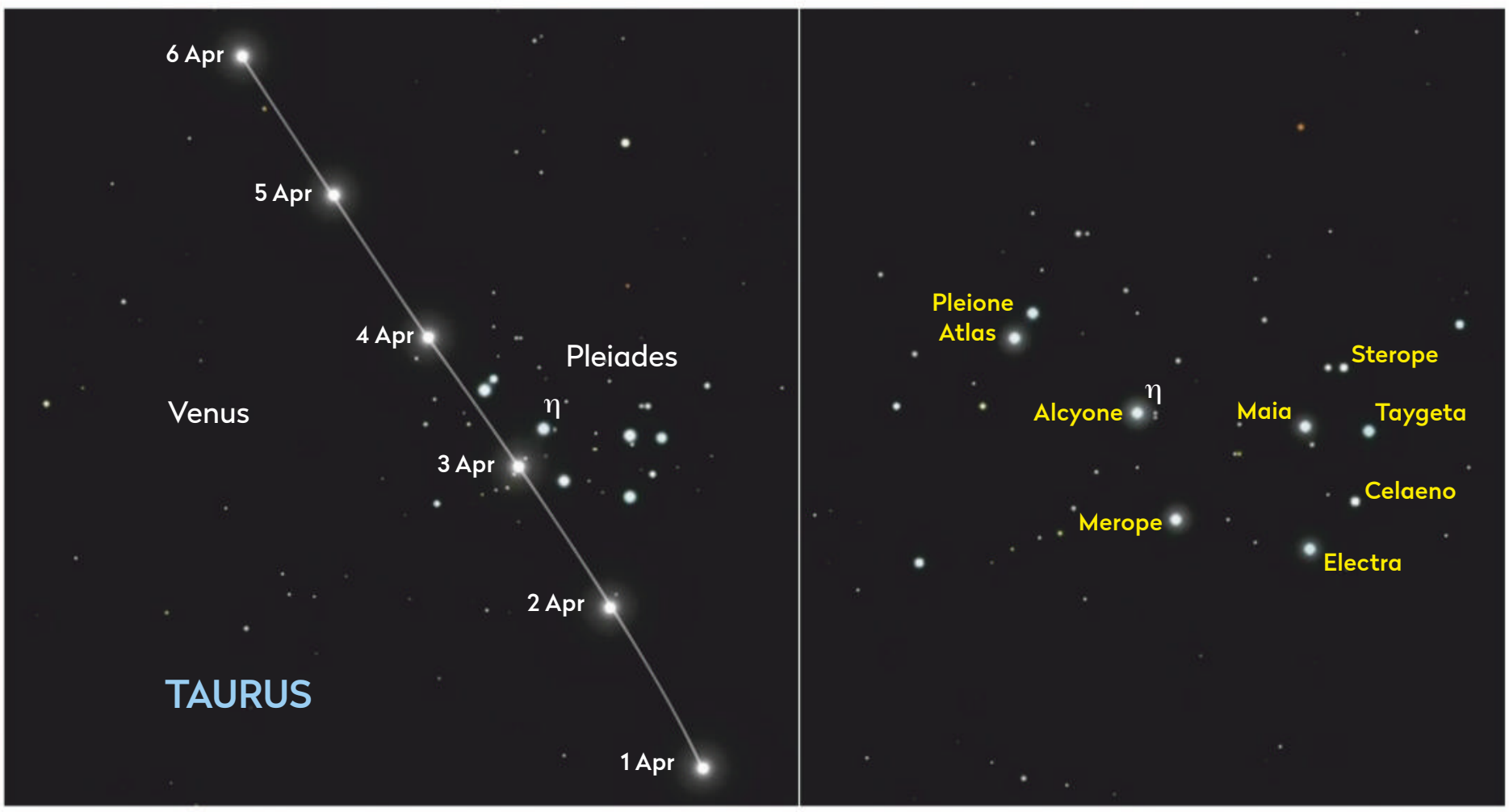
▲ **Venus and the Pleiades seen through cloud on 4 April 2012**

On 2 April, Venus will appear 1° from Alcyone. This will be a glorious sight through binoculars or a scope using a wide-field eyepiece. Cameras with longer focal length lenses or attached to a wide-field telescope can be used to achieve additional image scale.

Venus appears against the cluster stars on 3 April, tracking one-quarter of a degree south of Alcyone. Photography will present an interesting dilemma here. Venus is so bright that any extended exposure used in an attempt to bring out the reflection nebulosity associated with the cluster is likely to result in a blown out, over-exposed planet.

On 4 April, Venus appears east of the cluster. The main shape of the Pleiades is often described as appearing like a box with a handle. On 4 April, the handle gets an extension thanks to the positioning of the planet. On 5 April, Venus maintains its eastern march, now appearing 1.7° to the east of Alcyone.

Later in April, with Venus near to the star Elnath (Beta (β) Tauri), a crescent Moon will slip by to the south of the planet. Look out for this between 25–27 April.

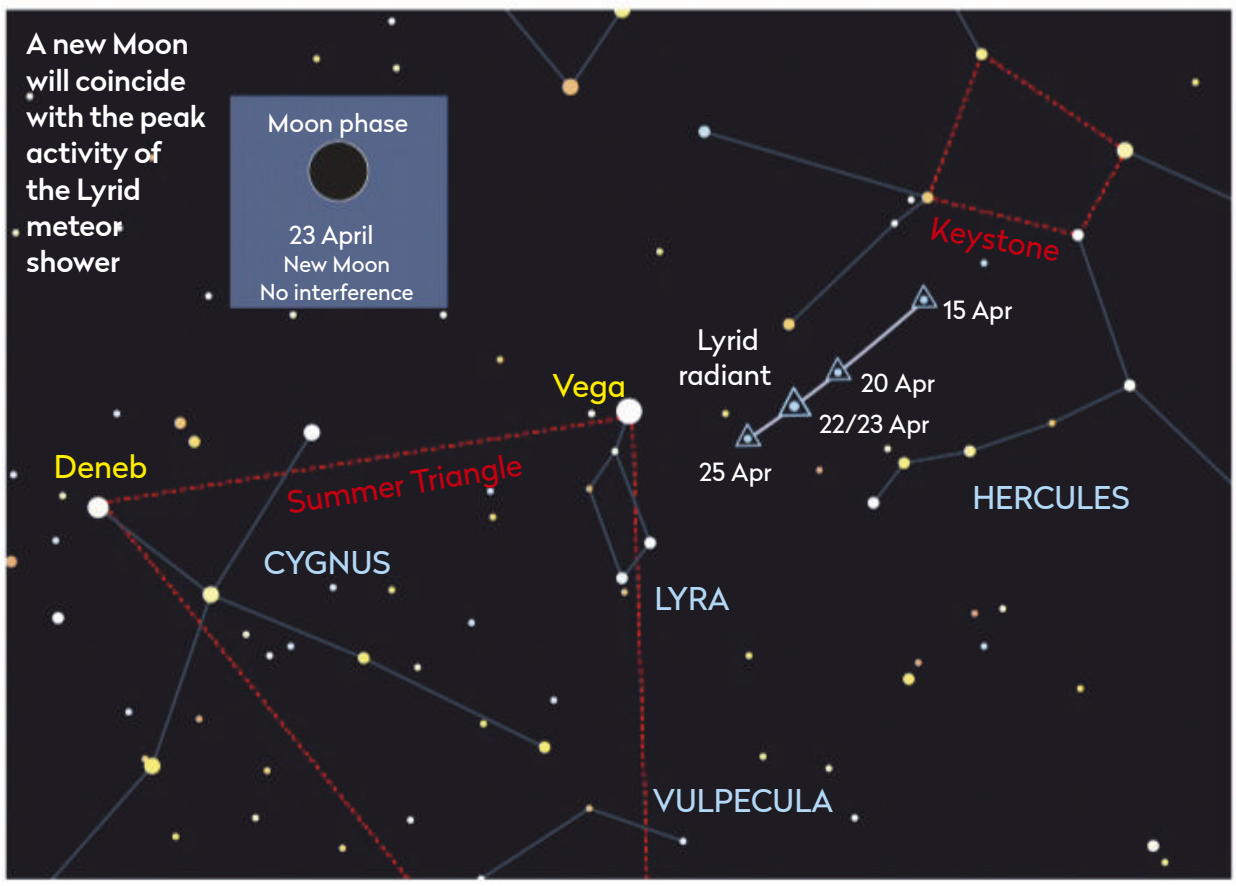


ALL PICTURES: PETE LAWRENCE

▲ **Left: movement of Venus through the Pleiades in early April, with positions for 23:00 BST (22:00 UT); Right: the main stars of the Pleiades**

Lyrid meteor shower

BEST TIME TO SEE: 14-30 April with shower peak on the morning of 22 April



The annual Lyrid meteor shower reaches peak activity this month. The shower is due to Earth passing through the dust spread around the orbit of comet C/1861 G1 Thatcher. Peak activity occurs on the morning of 22 April, Lyrid meteor trails appearing to come from a radiant near to the star Vega (Alpha (α) Lyrae).

Peak activity normally results in a Zenithal Hourly Rate (ZHR) of 18 meteors per hour, but elevated rates have been observed in the past. In 1982 a peak ZHR of 90 was recorded. This year's peak is expected to occur at 07:40 BST (06:40 UT) on 22 April, but over past years there has been variance. The peak 'zone' is expected to extend from 23:40 BST (22:40 UT) on 21 April to 10:40 BST (09:40 UT) on the 22nd. No enhanced activity is predicted but only observation will confirm it doesn't happen.

From the centre of the UK, true darkness falls around 22:40 BST (21:40 UT) on 21 April and lasts until 03:40 BST (02:40 UT) on the 22nd. The period from midnight BST (23:00 UT) until 03:40 BST (02:40 UT) is likely to be most productive, especially towards the end of the morning shift. At this time the radiant position will be almost overhead. A fortunate timing of new Moon on 23 April means the conditions for this year's display are optimal.

We recommend looking up at a height of 60° in any direction. Southeast has some interesting constellations and the Milky Way on view if your skies are dark. This view will include the radiant position in the early hours. Meteor trails close to the radiant will appear shorter due to perspective foreshortening. If you decide to observe the shower, it's important to allow your eyes 20 minutes of total darkness to become fully dark adapted. Avoid any further exposure to light until you've finished observing.

The Eyes of Clavius

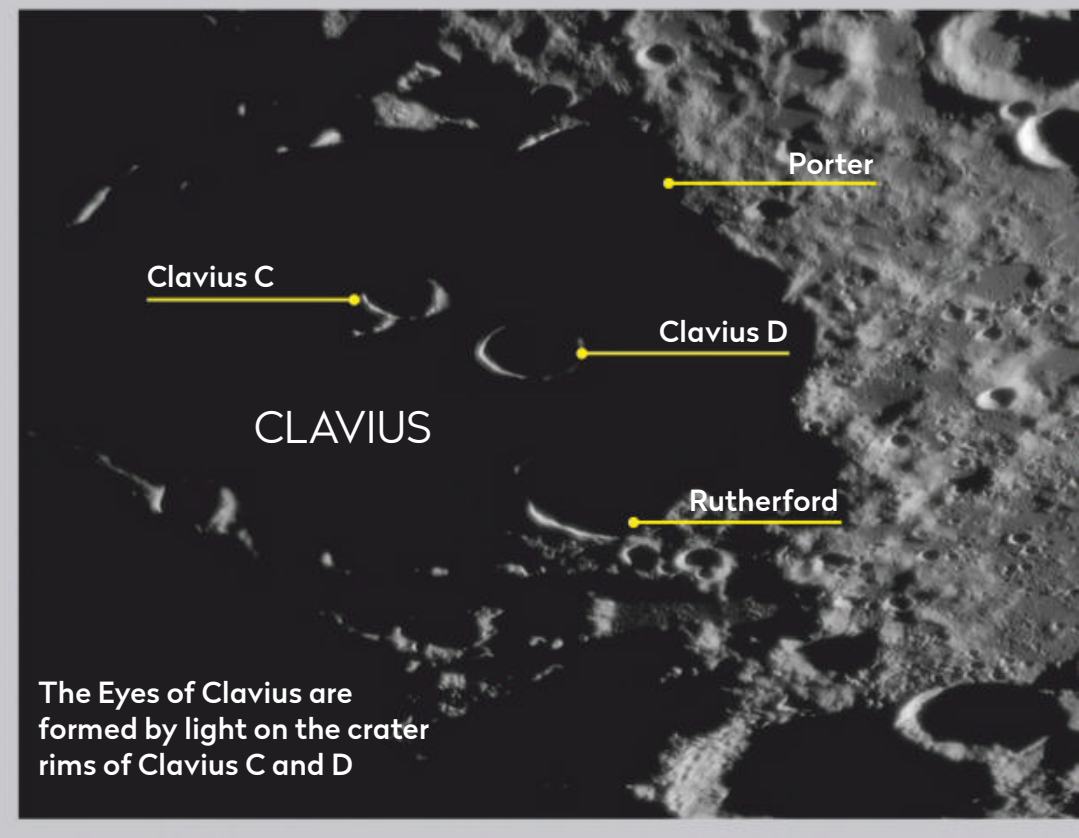
BEST TIME TO SEE: Early hours of 2 April

Clavius is a large crater visible in the southern region of the Moon's Earth-facing side. Its 225km-diameter rim appears heavily foreshortened from Earth due to its proximity to the Moon's southern limb.

The rim appears interrupted by smaller craters such as 53km Porter in the northeast and 55km Rutherfurd in the southeast. Inside Clavius is a curving arc of craterlets that appears to start at Rutherfurd arcing round to 28km Clavius D, 21km Clavius C, 13km Clavius N and 12km Clavius J.

Clavius C and D have rims raised above Clavius's floor. At certain times when the terminator is crossing Clavius, the C and D rims will catch the light of the early lunar dawn before it's had a chance to flood the main crater's floor. When this happens, the rims appear like large illuminated circles hovering in the dark. This forms the clair-obscur effect, a trick of the light, known as the Eyes of Clavius.

The eyes occur when the lunar terminator is at co-longitude 15°. This will be the case in the early hours of 2 April when the effect should be visible through a telescope's eyepiece. The Moon will be at the 56% waxing gibbous phase at this time.



The Eyes of Clavius are formed by light on the crater rims of Clavius C and D

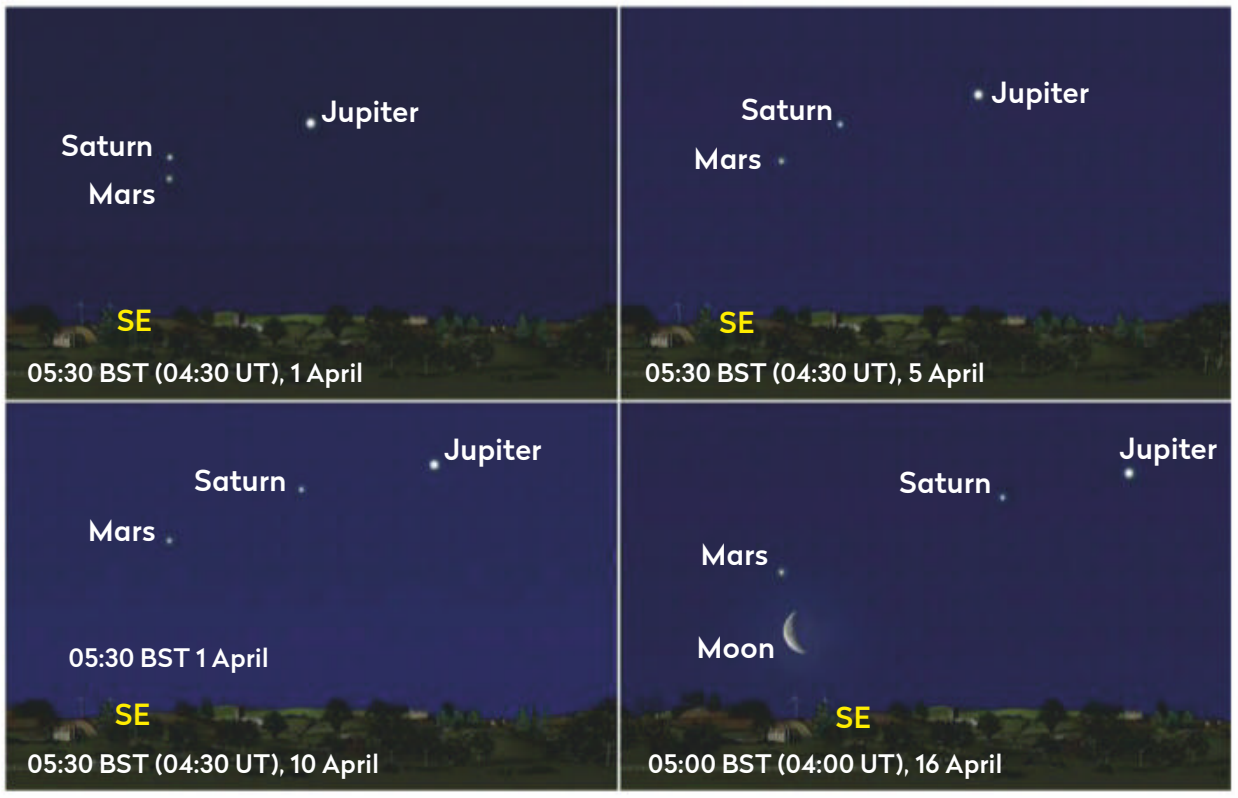
THE PLANETS

Our celestial neighbourhood in April

PICK OF THE MONTH

Mars

Best time to see: 1 April, from 75 minutes before sunrise
Altitude: 5° (low)
Location: Capricornus
Direction: Southeast
Features: Phase, dark markings, polar caps and weather
Recommended equipment: 75mm or larger

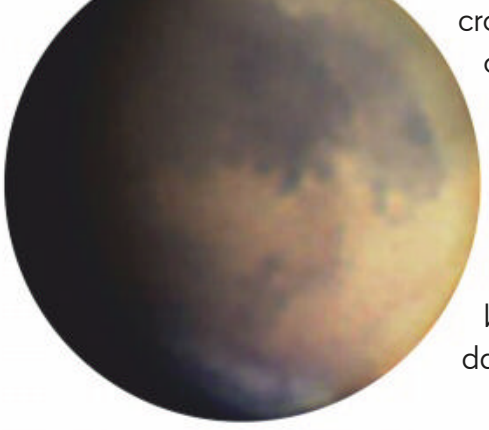


▲ **Mars, Jupiter and Saturn will appear close together in the early part of April**

Mars remains low as seen from the UK, currently visible above the southeast horizon in the early dawn twilight. On 1 April Mars lies a fraction under a degree south-southeast of Saturn. From the UK when due southeast, Saturn appears directly above Mars. With Mars at mag. +0.8 and Saturn at mag. +0.9 the 1st presents a good opportunity to compare the appearance of both objects in terms of colour. Saturn's off-white colour should contrast well against orange-hued Mars. The only issue here will be the rapidly brightening background sky, which will make their colours that bit harder to see. Jupiter is also nearby, located 6.3° west of Saturn. Together, all three should be a stunning sight in the morning sky.

On 1 April a telescopic view of Mars will show it to be 6 arcseconds across and presenting an 88%-lit phase. By the end of the month this will have changed slightly with the planet's apparent diameter slightly larger at 7 arcseconds and a marginally reduced phase of 86%. At the end of the month, Mars will appear brighter at mag. +0.4. On 16 April, mag +0.6 Mars will appear 2.8° north of a 37%-lit waning crescent Moon.

Mars is no slouch, and can appear to move rapidly against the background stars. Throughout April it heads east, almost managing to completely cross the west-east length of Capricornus. This eastward motion isn't particularly favourable in terms of positioning the planet for observation. It's rapid motion east keeps it embedded in the dawn twilight, the bright sky engulfing it as it attempts to gain any serious altitude. Things will improve over coming months but for the time being, Mars remains a tricky planet to observe through a telescope.

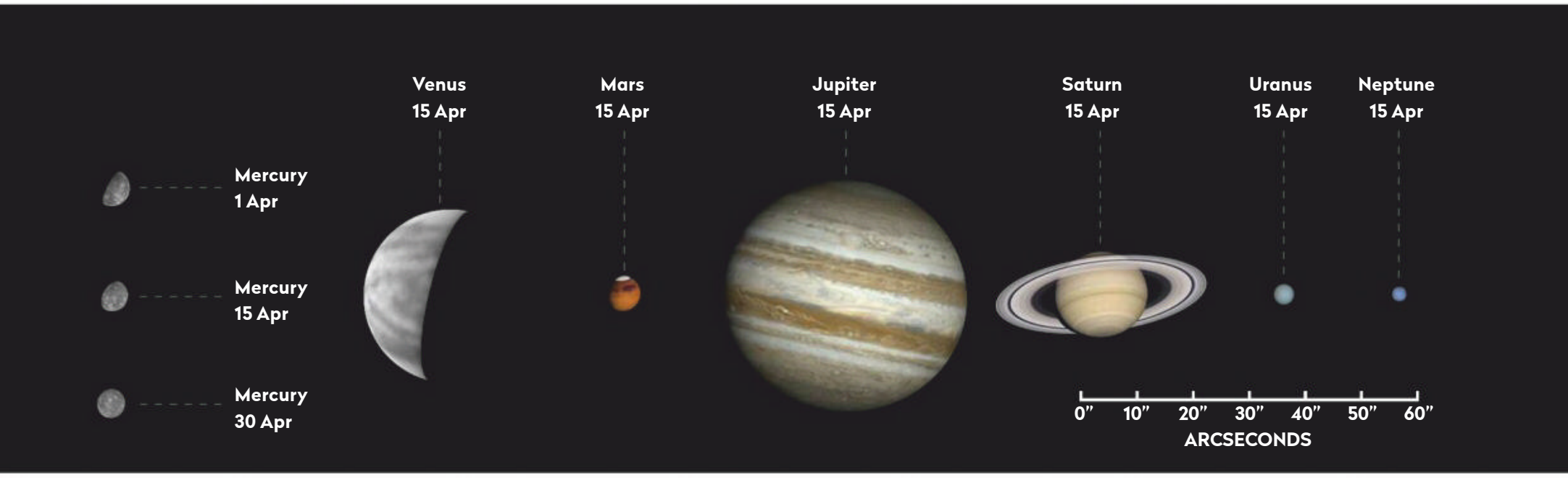


▲ **During April, Mars will appear to move rapidly against the background stars**

PETE LAWRENCE X 3

The planets in April

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



18+

WHAT IS AVAXHOME?

AVAXHOME-

the biggest Internet portal, providing you various content: brand new books, trending movies, fresh magazines, hot games, recent software, latest music releases.

Unlimited satisfaction one low price
Cheap constant access to piping hot media
Protect your downloadings from Big brother
Safer, than torrent-trackers

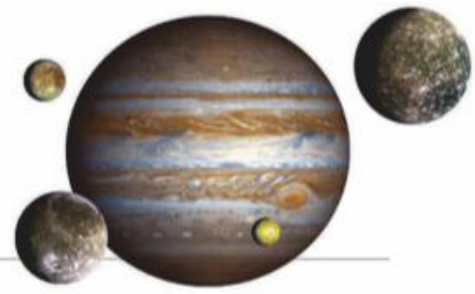
18 years of seamless operation and our users' satisfaction

All languages
Brand new content
One site

AVXLIVE.ICU

AvaxHome - Your End Place

We have everything for all of your needs. Just open https://avxlive.icu



Mercury

Mercury's poor morning appearance in March continues through April. The planet will be poorly placed in the morning sky and is unlikely to be seen.

Venus

Best time to see: 3 April, from 30 minutes after sunset
Altitude: 35°
Location: Taurus
Direction: West

Venus is a spectacular sight in the west after sunset. Shining at mag. –4.3, it will be approaching the Pleiades open cluster on 1 April, separated from the cluster stars by less than 2°. There's plenty of time to enjoy this view too, Venus remaining above the horizon for nearly five hours after sunset on 1 April, three hours in true darkness.

The planet-cluster separation is less than 1° on 2 April, with Venus appearing to pass in front of the cluster stars on the evening of the 3rd. As the planet and cluster will be visible against a dark background, it will open up opportunities for imaging. On 4 April, Venus will appear 0.4° to the east of the star Atlas, the easternmost of the main Pleiades stars. However, the positioning will be perfect. The Pleiades looks like a box with a handle and the placement of Venus on the evening of 4 April serves to extend that handle.

Through a scope, things are changing rapidly too. On 1 April, Venus presents a 25 arcsecond disc, 46%-illuminated. By the month's end the Venusian disc appears 38 arcseconds across and shows a 25% phase.

The planet's monthly visit from the Moon occurs on 26 April when a 12%-lit waxing crescent Moon sits 6.5° south of Venus. As April's end approaches don't become complacent with Venus's appearance in the evening twilight sky. Having been a dominant fixture for several months, it's now moving along the part of its orbit closest to Earth. Its favourable position in the sky and dominant appearance will change. Venus will set four hours after the Sun at the end of April, one hour less than it did at the month's start.

Jupiter

Best time to see: 30 April, 90 minutes before sunrise
Altitude: 10°
Location: Sagittarius
Direction: Southeast

A low morning planet that currently appears close to Saturn. A 47%-lit waning crescent Moon is nearby on 15 April, forming an isosceles triangle with Jupiter and Saturn. Jupiter shines at mag. –2.2 by the end of the month, which makes it the second brightest planet in the sky after Venus. As an aside, Jupiter appears 45 arcminutes from Pluto on the morning of 4 April.

Saturn

Best time to see: 30 April, 90 minutes before sunrise
Altitude: 9°
Location: Capricornus
Direction: Southeast

Saturn is in Capricornus and visible in the morning sky near to Jupiter. A 47%-lit waning crescent Moon sits nearby on the morning of 15 April. Saturn currently shines at mag. +0.9.

Neptune

A morning planet, Neptune is not well placed for observing.

NOT VISIBLE THIS MONTH:

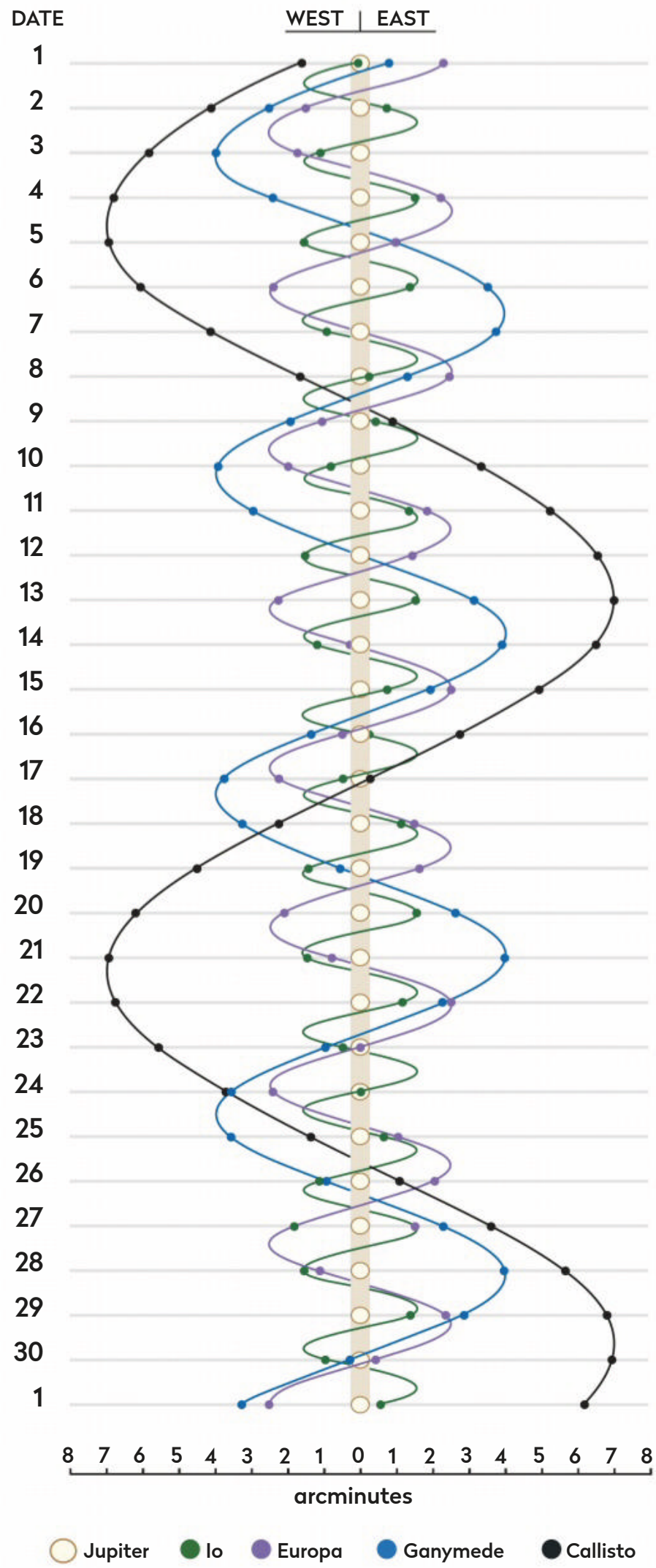
Uranus

Uranus is in conjunction with the Sun on 26 April and not visible this month.

More ONLINE
Print out observing forms for recording planetary events

JUPITER'S MOONS: APRIL

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – APRIL

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

Arcturus — STAR NAME

PERSEUS — CONSTELLATION NAME

GALAXY

OPEN CLUSTER

GLOBULAR CLUSTER

PLANETARY NEBULA

DIFFUSE NEBULOSITY

DOUBLE STAR

VARIABLE STAR

THE MOON, SHOWING PHASE

COMET TRACK

ASTEROID TRACK

STAR-HOPPING PATH

METEOR RADIANT

Circlet — ASTERISM

PLANET

QUASAR

STAR BRIGHTNESS:

MAG. 0 & BRIGHTER

MAG. +1

MAG. +2

MAG. +3

MAG. +4 & FAINTER

5° N W E S — COMPASS AND FIELD OF VIEW

MILKY WAY

When to use this chart

1 April at 01:00 BST
15 April at 00:00 BST
30 April at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in April*

Date	Sunrise	Sunset
1 Apr 2020	06:43 BST	19:46 BST
11 Apr 2020	06:19 BST	20:04 BST
21 Apr 2020	05:56 BST	20:23 BST
01 May 2020	05:35 BST	20:41 BST

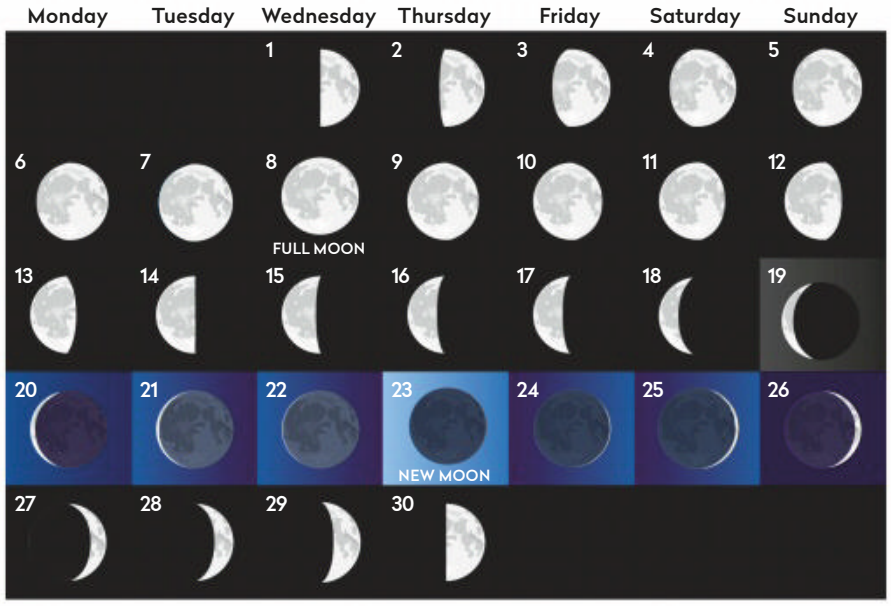
Moonrise in April*

Moonrise times

1 Apr 2020, 10:57 BST	17 Apr 2020, 04:55 BST
5 Apr 2020, 16:05 BST	21 Apr 2020, 06:01 BST
9 Apr 2020, 22:07 BST	25 Apr 2020, 07:07 BST
13 Apr 2020, 02:10 BST	29 Apr 2020, 09:48 BST

*Times correct for the centre of the UK

Lunar phases in April



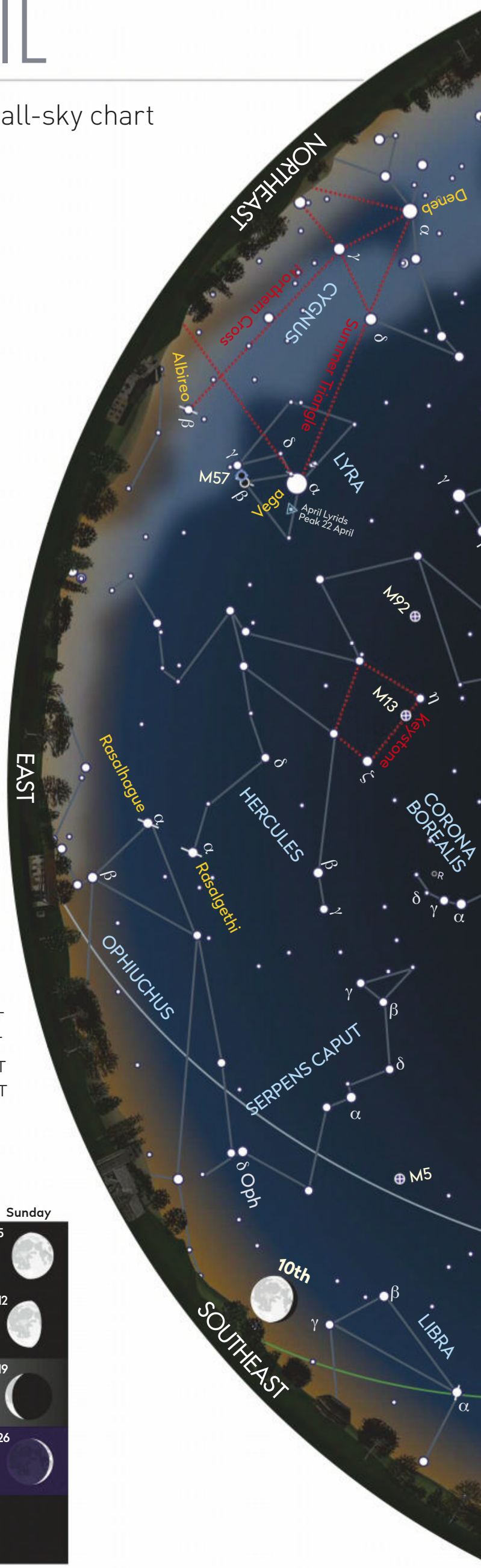


CHART: PETE LAWRENCE

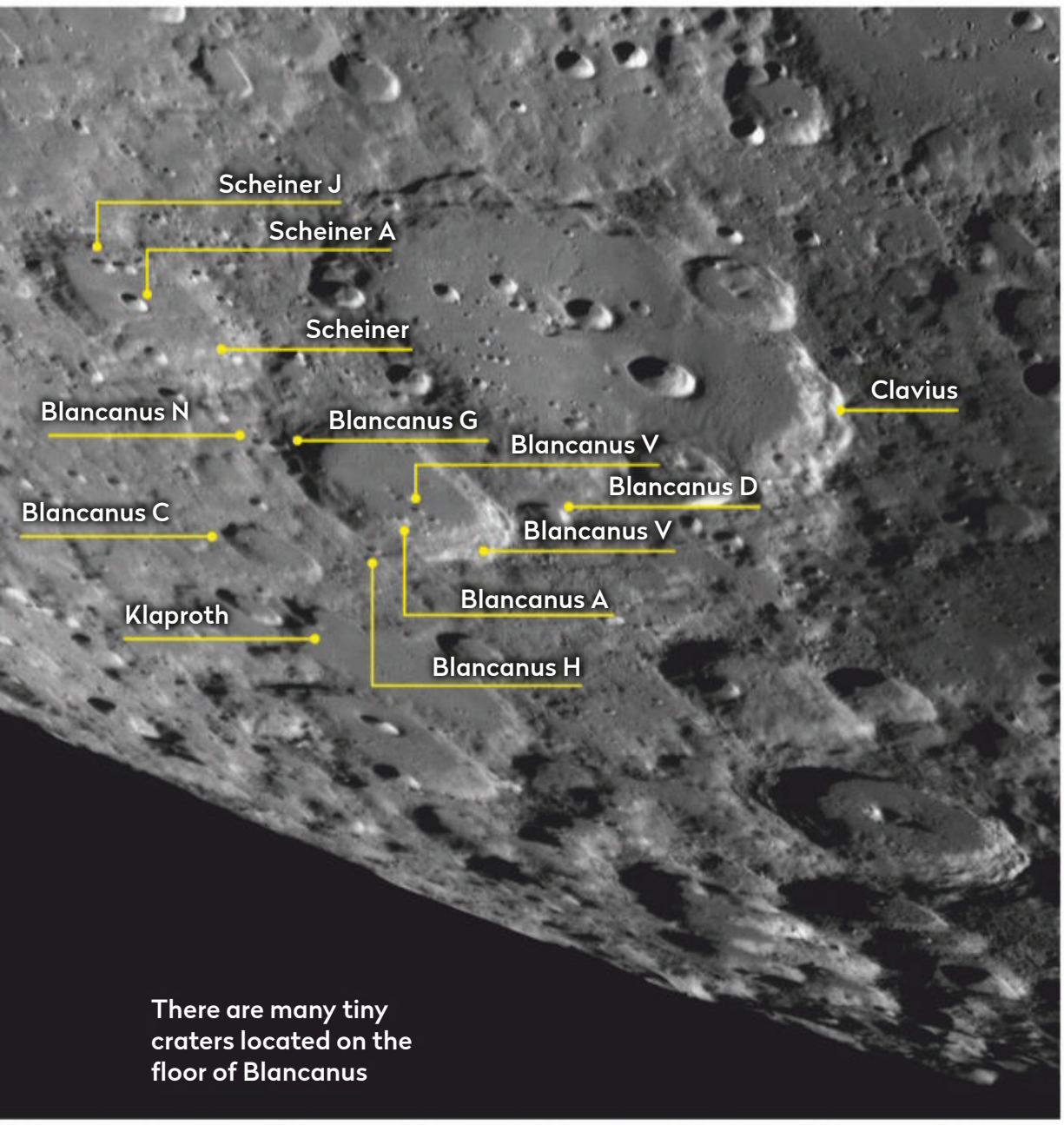
MORE **ONLINE**

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

MOONWATCH

April's top lunar feature to observe

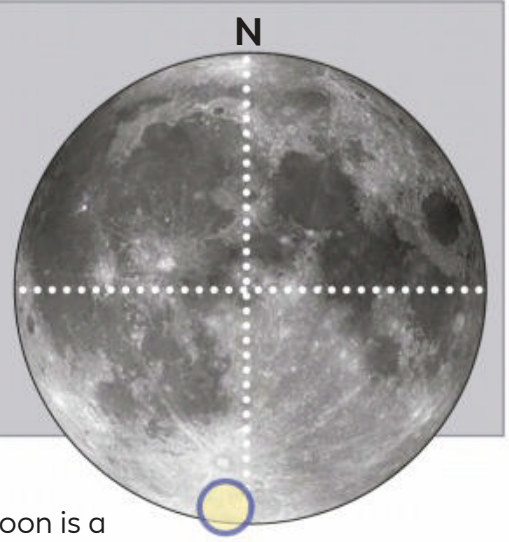


There are many tiny craters located on the floor of Blancanus

PETE LAWRENCE X 5

Blancanus

Type: Crater
Size: 106km
Longitude/latitude: 21.6° W, 63.8° S
Age: Older than 3.9 billion years
Best time to see: Two days after first quarter (2 April) and one day after last quarter (16-17 April)
Minimum equipment: 10x50 binoculars



It's sometimes easy to forget that the Moon is a three-dimensional object. When we look at it from Earth, apart from slight libration variations, its features are the same one month to the next. Located around 384,400km away from Earth, the Moon is too far for our eyes to see in a way that allows us to perceive depth. However, looking at it through a telescope emphasises its physical shape and nothing does this better than observing round craters close to the Moon's edge.

This month's *Moonwatch* target is the crater **Blancanus** located just to the south of the large, impressive walled plain of 225km **Clavius**. Blancanus itself is also quite large at 106km, but being close to the Moon's southern edge, it appears foreshortened into an ellipse.

Blancanus is well defined with terraced rim walls leading down to a flat floor

The foreshortening varies depending on the Moon's libration state. Libration is the phenomenon that causes the Moon's globe to rock and roll slightly seen from Earth, caused by the Moon's tilted and elliptical orbit. However, despite being a large lunar feature in its own right, Blancanus never stands out like more centrally located craters such as 93km **Copernicus**. To be fair, this is in part also due to the local surroundings for both craters. Copernicus is surrounded by lava and sits at the centre of an extensive ejecta ray system. Blancanus doesn't fare as well, being surrounded by many other craters. Some are larger, some smaller and many are a similar size. Examples include 110km **Scheiner** to the west and 119km **Klaproth** to the southeast.

Blancanus itself is well defined with wide terraced rim walls leading down to a flat floor. Although there's no demonstrative central mountain peak complex, there is a set of low altitude hills offset to the southwest of Blancanus's centre. There are numerous tiny craterlets on its floor, the largest of which are 7km **Blancanus V** and 6km **Blancanus A**.

Three notable craters interrupt Blancanus's rim: 7km **Blancanus H** in the south, and the close pair of 9km **Blancanus G** and 11km **Blancanus N** to the west. Below the main crater is 46km **Blancanus C** which, by virtue of appearing even closer to the Moon's southern edge, is even more influenced by libration.

The three similar-sized craters Scheiner, Blancanus and Klaproth are quite different in appearance. Klaproth has a flat floor and is defined by a very irregular rim. Scheiner's rim is also quite battered and in terms of definition, sits somewhere between Blancanus and Klaproth. All three are devoid of central mountains but Scheiner's floor looks quite rough towards the east. Its western half is dominated by 12km **Scheiner A**, 12km **Scheiner J** and a 12km unnamed crater.

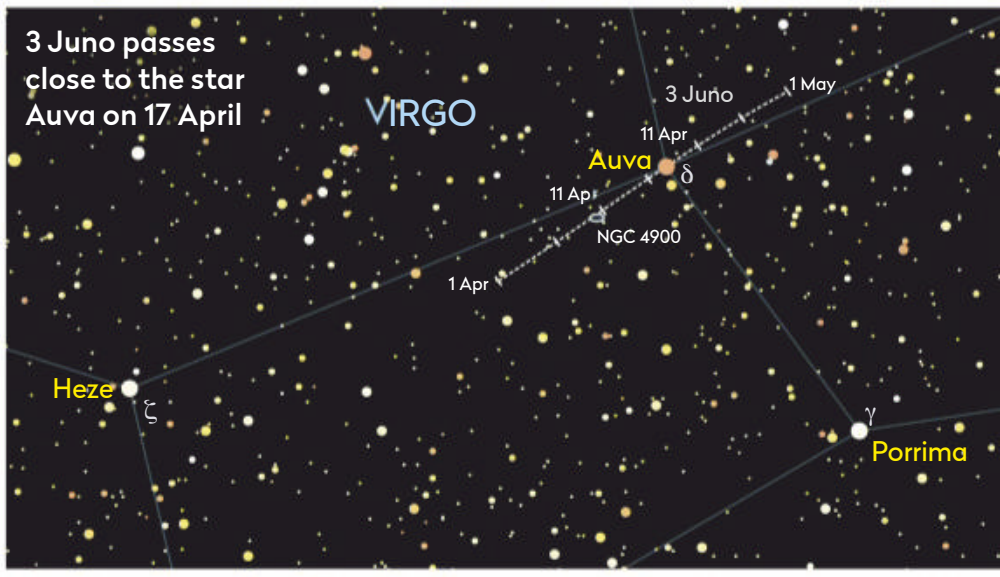
Lunar libration causes large variations in the appearance of Blancanus this month and if you have clear skies, try looking for it anywhere between 2–17 April. The crater will be most notable when the terminator is nearby (as indicated by our 'Best time to see' dates) but if you can locate it when the region is more fully illuminated, the view will reveal just how different it can appear between favourable and unfavourable libration states.

COMETS AND ASTEROIDS

Asteroid 3 Juno reaches opposition on 2 April in the constellation of Virgo

Asteroid 3 Juno is one of the larger bodies in the asteroid belt. It reaches opposition on 2 April 2020, within the main body of Virgo. On 1 April it shines at mag. +9.6 and is located just south of the two-thirds position along a line from mag. +3.4 Heze (Zeta (ζ) Virginis) towards Auva (Delta (δ) Virginis), which is also of mag. +3.4. It then follows a path towards Auva, performing a very close apparent pass of this star on 17 April. The asteroid remains at mag. +9.6 through opposition, two magnitudes fainter than it can achieve at perihelic oppositions – when Juno is at its closest to the Sun. As it appears to trundle through Virgo, 3 Juno will pass the mag. +11.3 galaxy NGC 4900 on the evening of 10 April. It dims to mag. +10 on 26 April, a magnitude it then maintains until the end of the month.

Juno is the 11th largest asteroid with tri-axial ellipsoid dimensions of 320 x 267 x 200km and a mean diameter of 247km. It is the second largest stony (siliceous or S-type) asteroid, the largest being 15 Eunomia, and contains an estimated 1 per cent of the entire mass of the asteroid belt. This pales into insignificance compared to the largest object in the asteroid belt, dwarf planet Ceres, Juno's mass being just 3 per cent that of Ceres. Juno's elliptical orbit is highly eccentric and takes it out as far as 3.35 AU (where 1 AU is the distance between the Sun and the Earth) from the Sun at aphelion, and in as close as 1.99 AU at perihelion. The entire orbit takes 4.36 years to complete and is quite inclined, with a tilt of 12° to the ecliptic plane.



Analysis of Juno's spectrum has led to a theory that this body could be the source of chondritic, or stony, meteorites. A series of images made using ALMA (Atacama Large Millimeter/submillimeter Array) have revealed a great deal of information about Juno, showing us much of a single rotation and resolving large surface features. There is evidence that the asteorid 3 Juno has a massive 100km impact crater on its surface.

STAR OF THE MONTH

Dubhe, the 'Pointer' star at the Plough's northeast corner

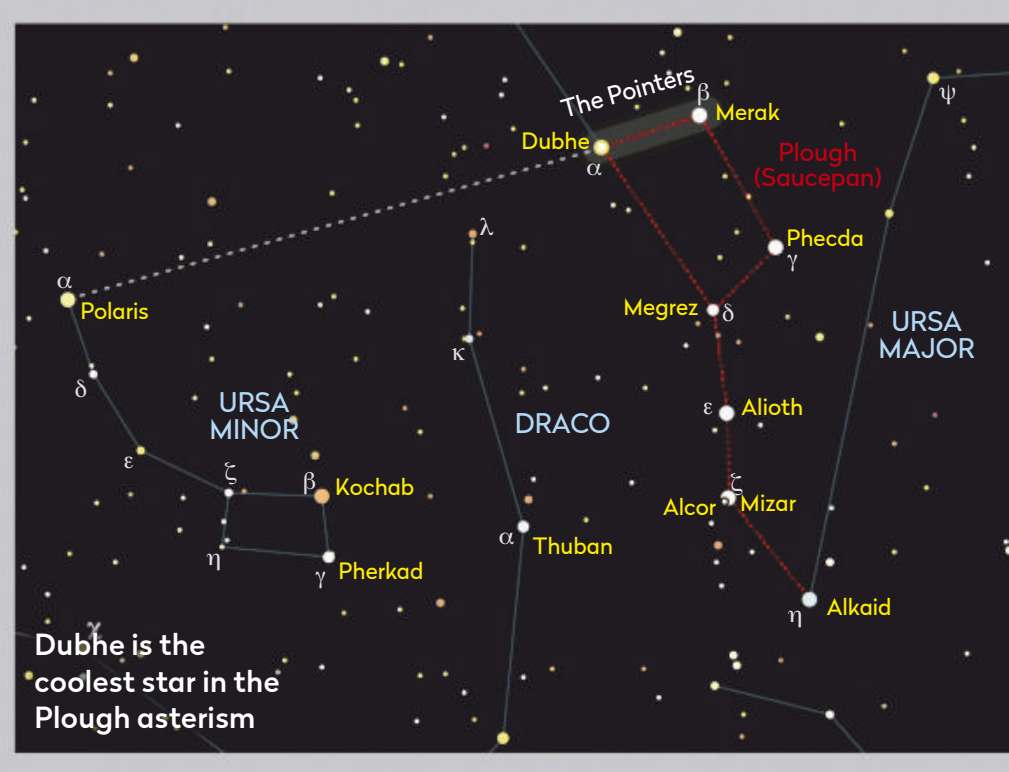
Dubhe (Alpha (α) Ursae Majoris) is one of the pointer stars in the familiar asterism known as the Plough or Saucepan. It marks the northeast corner of the Plough's blade or Saucepan's pan however you see it. The second pointer star is Merak (Beta (β) Ursae Majoris). A line extended from Merak through Dubhe eventually brings you to the North Star, Polaris (Alpha (α) Ursae Minoris); hence the term 'Pointers'.

Dubhe shines at mag. +1.8 and is located 123 lightyears from the Sun. Despite its designation as Alpha Ursae Majoris, Dubhe is actually the second brightest star in Ursa Major. The brightest is Alioth (Epsilon (ε) Ursae Majoris), the third star in from the end of the Plough's handle. The reason for the non-brightness lettering sequence is that Bayer labelled the stars in the Plough from east to west. Consequently, if you know the first seven letters of the Greek alphabet – alpha (α), beta (β), gamma (γ), delta (δ), epsilon (ε), zeta (ζ), eta (η) – then you can deduce the Bayer designation of the stars in the Plough easily.

Of the seven stars that form the Plough, the inner-five, Beta (β), Gamma (γ), Delta (δ), Epsilon (ε) and Zeta (ζ) Ursae Majoris are all part of a cluster located at a distance of 80 lightyears. Dubhe and Alkaid (Eta (η) Ursae Majoris) aren't part of this cluster and over time will move in different directions to the other five stars.

Of the seven stars Dubhe is the coolest, the other six being hot blue-white stars. Dubhe has a spectral class of K0III, indicating that it's an orange giant star. When you look at the Plough see if you can spot the difference in colour between Dubhe and the other stars in the pattern.

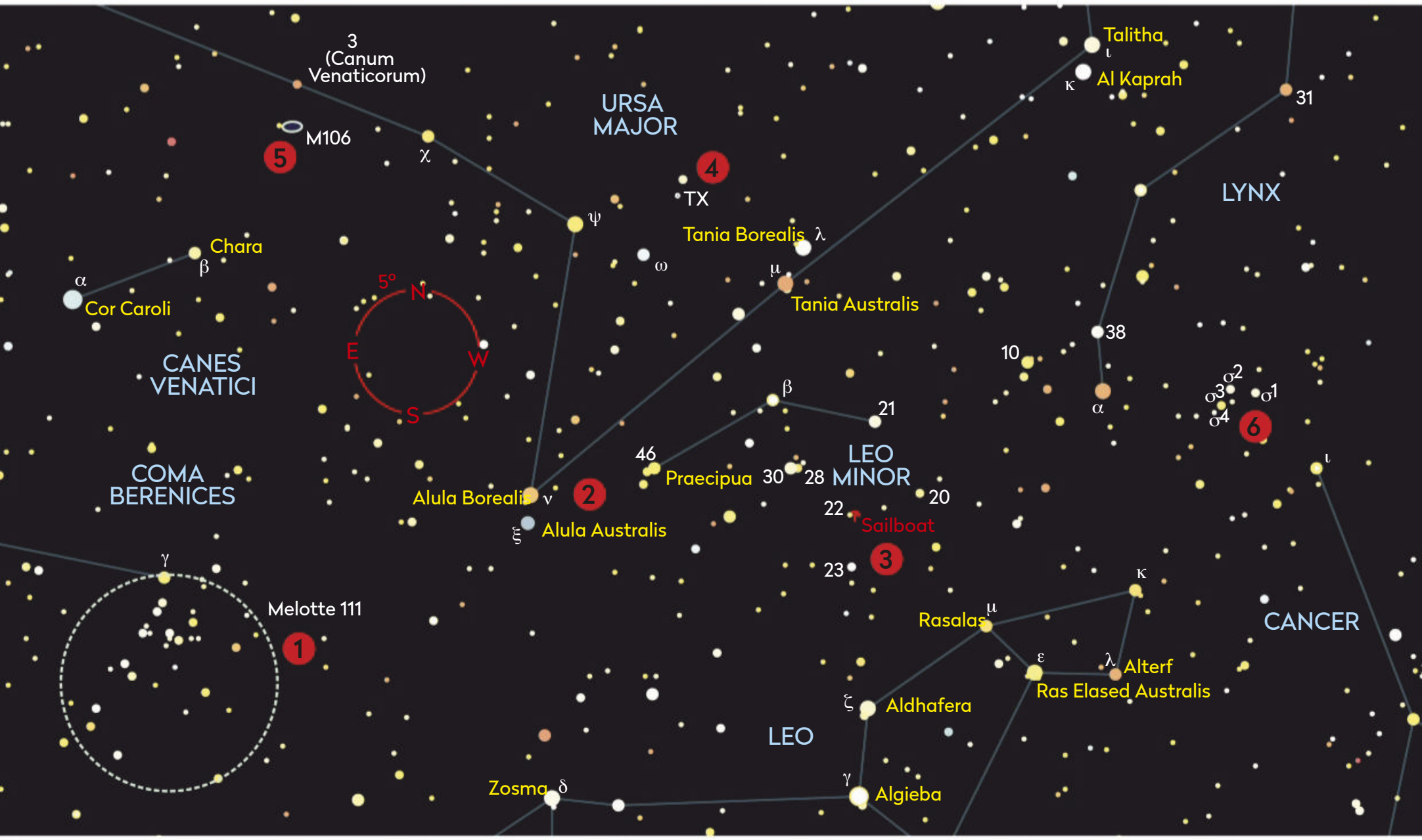
Dubhe is a spectroscopic binary star system. The primary, Dubhe A, is 4.3 times as massive as the Sun, the secondary 1.6 times. Dubhe A is also over 300 times more luminous than the Sun. The name Dubhe derives from 'the bear' in Arabic.



BINOCULAR TOUR

With Steve Tonkin

We find the trail of an ancient gazelle among this month's wide-field treasures



1. Melotte 111

10x 50 On a good night you will see, in the region of Gamma (γ) Comae, a large misty patch. Binoculars will reveal a huge cluster of stars; you should be able to resolve at least 30. To the ancient Greeks, this was Berenice's hair, and is what gives the constellation Coma Berenices its name; to the Babylonians, it was Thisbē's veil, and to the Arab peoples of north Africa it was a watering hole. ☐ **SEEN IT**

2. Three Leaps of the Gazelle

10x 50 Our next asterism occupies three different locations, each featuring two stars, spread over 30° of sky. In Arabic sky lore these are the hoof-prints left by a gazelle that, startled by a lion (Leo is visible at the south of the chart), leapt from the watering hole. They are all naked-eye stars, but binoculars will help to bring out the colour differences, ranging from orange Alula Borealis (Nu (ν) Ursae Majoris) to brilliant white Kappa (κ). ☐ **SEEN IT**

3. The Sailboat

15x 70 Use the chart to identify the location of 22 Leonis Minoris; it is in the centre of a triangle made by 20, 23 and 28/30 Leonis Minoris. Once you have it in your binoculars you will notice that 22 itself is the brightest of a group of nine stars that form an inverted sailing dinghy. The brighter four stars form the hull, while the keel and orange mast are picked out by 9th magnitude stars. ☐ **SEEN IT**

4. TX UMa

10x 50 Return to the second leap of the gazelle and navigate 6° northeast to a slightly off-white mag. +5.2 star. You will find our next target about half a degree south of this. TX Ursae Majoris is an eclipsing binary star that varies between mag. +7.1 and mag. +8.8, with a period of 73.5 hours. If you observe it regularly, a month or so should be sufficient for you to detect its variability. ☐ **SEEN IT**

5. M106

15x 70 You'll need a dark sky for our next target. Locate the 5th magnitude orange star 3 Canum Venaticorum, which makes the right angle of a triangle with Chara (Beta (β) Canum Venaticorum) and Chi (χ) Ursae Majoris. More than half a degree south of this is the faint glow of M106's nucleus. With averted vision, you may see it elongate in a southeast-northwest orientation. ☐ **SEEN IT**

6. Sigma Cancri Group

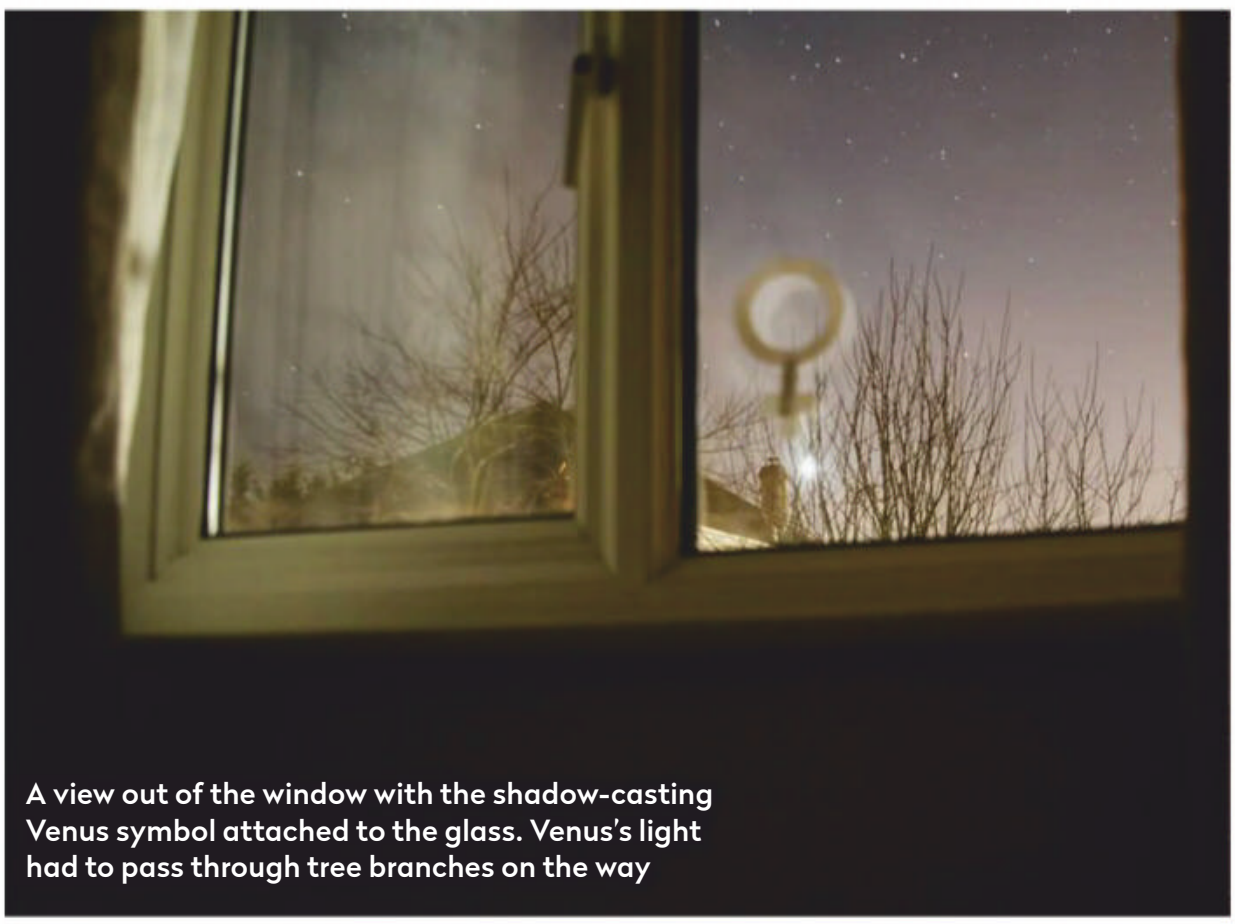
10x 50 Take a look at the Sigma (σ) Cancri stars in your binoculars and see how they appear to be part of a large, loose open cluster of stars. Don't deceive yourself: this is not a cluster, but merely a chance line of sight phenomenon. Now pan 3° to the west, and you'll see another pseudo-cluster. There are a few more of these in this general region; how many can you find? ☐ **SEEN IT**

☑ Tick the box when you've seen each one

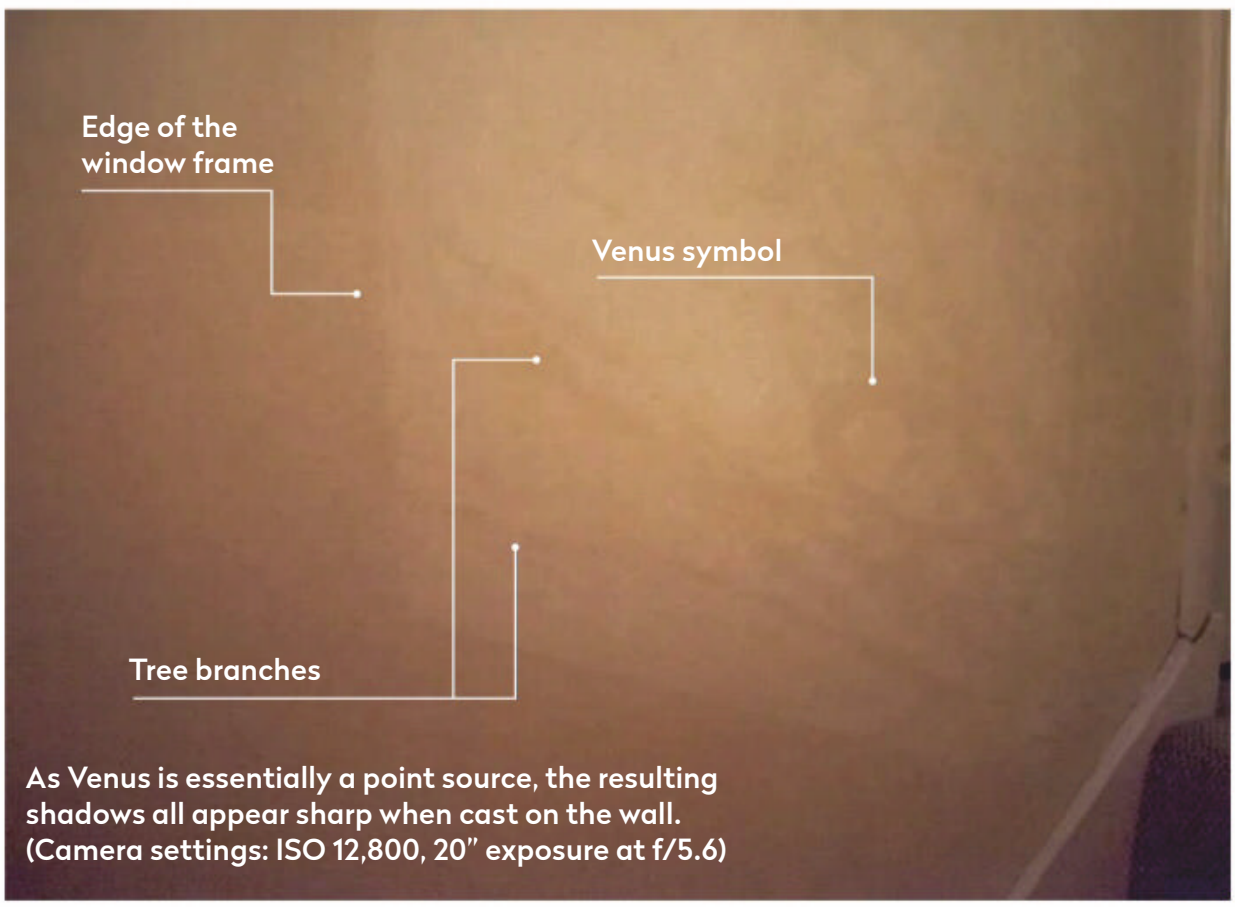
PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Try and capture a shadow cast by the light of the brilliant planet Venus



A view out of the window with the shadow-casting Venus symbol attached to the glass. Venus's light had to pass through tree branches on the way



As Venus is essentially a point source, the resulting shadows all appear sharp when cast on the wall. (Camera settings: ISO 12,800, 20" exposure at f/5.6)

Venus is currently unmistakable in the evening twilight after sunset. At the start of April, it's above the horizon nearly five hours after the Sun goes down. As the sky reaches true astronomical darkness, the appearance of this mag. –4.3 planet is really something to behold.

Venus's brilliance comes about because it is a planet covered in reflective clouds which is close to the Sun and Earth. This month's challenge is to see whether you can capture something which has rarely been photographed or seen visually, a shadow cast by Venus's light. Although Venus is quite brilliant, its delicate shadow is easily lost due to extraneous lighting. Creating a dark environment to isolate the shadow is quite hard and requires thought.

For this to work you'll need to see Venus against an astronomically dark sky

Try and pick a night when the sky is clear and the Moon is not about. You'll also need a relatively flat west to northwest horizon. For this to work you'll need to be able to see Venus against an astronomically dark sky. This occurs around 22:00 BST (21:00 UT) at the start of April and 23:15 BST (22:15 UT) at the month's end. A room with a west-facing window is ideal, but if one is not available, the next best thing is a cardboard box with one open end.

A shadow viewing screen can be made out of sheets of white paper fixed to a wall or used for lining the inside of a box. The shadow casting target is your choice; a cut out of the word 'Venus' or perhaps its planetary symbol ♀. If you're using the box option, ensure the target is rigidly fixed so it can't move in a breeze.

Next, unless you're in a really dark environment with crystal-clear skies, a camera will be required to record the shadow. A DSLR or MILC camera is ideal. Set to a high ISO, a low f/number and use a remote shutter release to avoid camera shake. A tripod allows you to point the camera easily. Illuminate the screen before your attempt, manually focusing on it as accurately as you can.

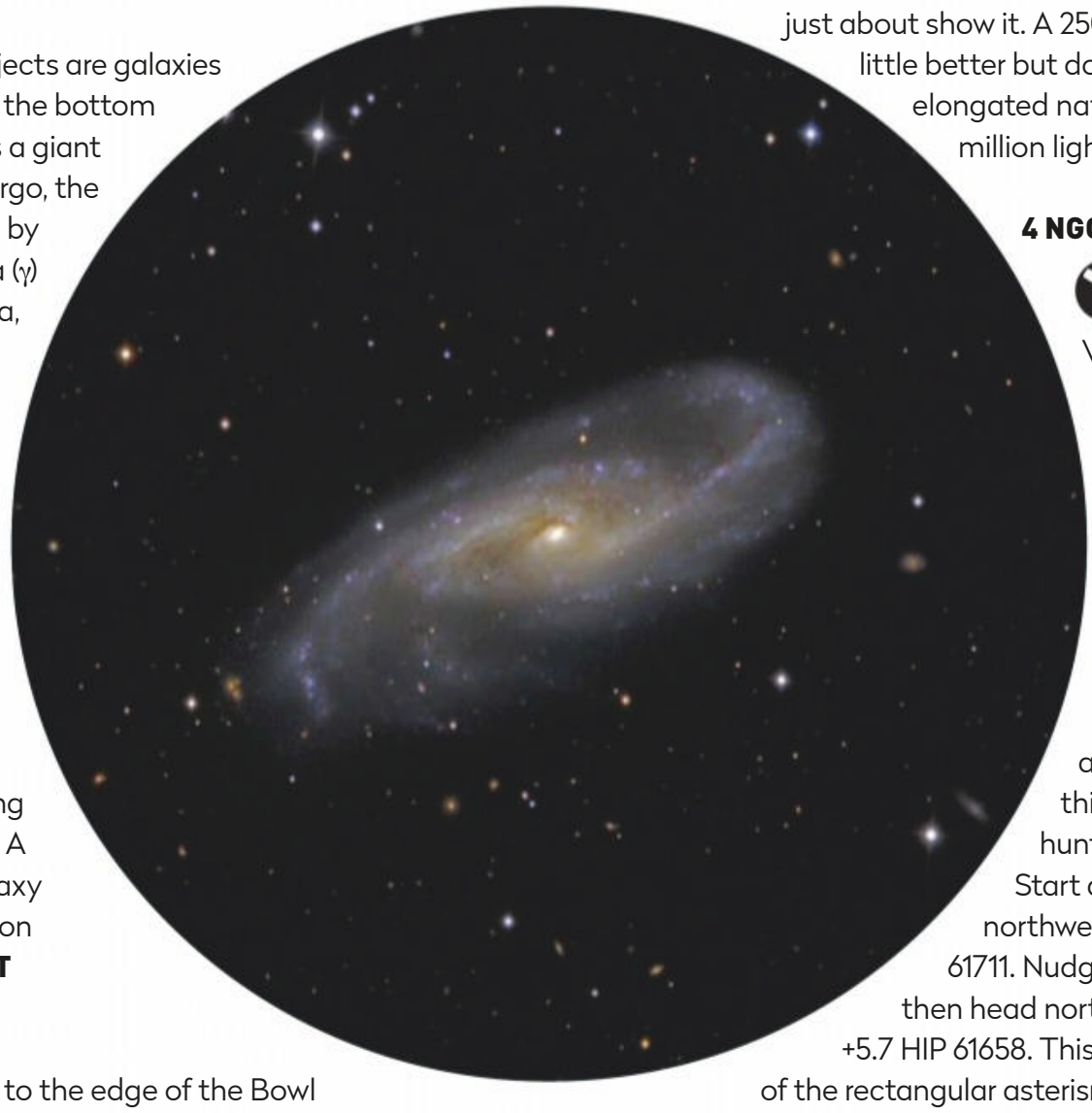
Do a test exposure of a few seconds up to tens of seconds. You may need to stretch the image using a photo editor – open levels and adjust the sliders to just encompass the histogram peak – to reveal the shadow. A useful technique is to make a time-lapse. As Venus sets, this reveals the shadow slowly creeping up the screen. The non-shadowed area may change colour as the atmosphere makes the planet's light slightly redder as it approaches the northwest horizon.

DEEP-SKY TOUR

We search for galaxies at the bottom of the Bowl of Virgo

1 NGC 4753

This month's objects are galaxies located close to the bottom of the Bowl of Virgo. This is a giant semi-circular asterism in Virgo, the bottom of which is marked by mag. +2.7 Porrima (Gamma (γ) Virginis). Starting at Porrima, heading east by 2.8° will bring you to the lenticular (shaped like an eye lens) galaxy NGC 4753. At mag. +9.9 this is an easy target for a 150mm scope, appearing as a 2 x 1.5 arcminute elliptical glow with a star-like nucleus. A 250mm scope shows a similar view with a hint of a dark feature cutting across the northeast edge. A member of the Virgo II Galaxy Group, it's around 60.5 million lightyears away. ☐ **SEEN IT**



▲ **Keep looking: spiral galaxy NGC 4536 will test your hunting skills**

MICHAEL BREITE/STEFAN HEUTZ/WOLFGANG RIES/ CCDGUIDE.COM, CHART BY PETE LAWRENCE

2 NGC 4666

We move closer to the edge of the Bowl asterism for a highly inclined spiral galaxy known as NGC 4666. Shining with an integrated magnitude of +10.8, NGC 4666 lies 1.3° northeast of Porrima and is visible in a 150mm scope. Its almost edge-on nature presents an object which appears around 3 arcminutes-long but just 0.5 arcminutes wide; a glowing streak. A 250mm scope will reveal the core region as a thin bright elongated feature within the larger halo. The extremities of this galaxy, the thin ends of the outer halo furthest from the core, are indistinct. It's around 80 million lightyears away. ☐ **SEEN IT**

3 NGC 4517

Spiral galaxy NGC 4517 lies within the Bowl asterism and exemplifies the difficulties navigating this part of the sky because, although the Bowl contains many galaxies, there are few stars which can be used to navigate to them. For NGC 4517, head west from Porrima for 1.8° to locate mag. +7.1 HIP 61358. Head north for 1.1° and west a further 0.3° to reach mag. +8.3 HIP 61240. NGC 4517, also known as Reinmuth 80, lies 0.4° and a fraction west of this star. It's a mag. +10.4 object with low surface brightness. A 150mm scope will just about show it. A 250mm instrument fares little better but does manage to reveal its elongated nature. NGC 4517 is 40 million lightyears distant. ☐ **SEEN IT**

4 NGC 4536

We move further into the Bowl of Virgo for an intermediate spiral known as NGC 4536. This has a magnitude of +10.4 but low surface brightness, which makes it faint in smaller scopes. A 250mm scope shows its elongated outline well, the galaxy appearing stretched into a 6 x 2 arcminute ellipse. Locating this galaxy takes even more hunting skill than NGC 4517. Start at Porrima and head 0.9° northwest to locate mag. +7.2 HIP 61711. Nudge your scope 0.1° west, then head north for 2.7° to locate mag. +5.7 HIP 61658. This forms the eastern corner of the rectangular asterism marked on our chart from which you should be able to find NGC 4536. It's around 49 million lightyears away. ☐ **SEEN IT**

5 NGC 4527

At the same magnitude of +10.4 as NGC 4536, our next target, another intermediate galaxy called NGC 4527, is easier to see. Visible in a 150mm scope, it appears as an elongated elliptical glow 3x0.7 arcminutes in size. If you managed to locate target 4, NGC 4536, locating NGC 4527 will be a breeze because it's located just 28 arcminutes further north. A 250mm instrument shows the galaxy nicely, its outline appearing distinct against the surrounding space. Photos show NGC 4527 to look similar in appearance and inclination to the Andromeda Galaxy. NGC 4527 is estimated to be 49 million lightyears away. ☐ **SEEN IT**

6 NGC 4636

NGC 4636 is an elliptical galaxy which is 53 million lightyears from Earth. It requires a bit of navigational skill to locate manually, forming the eastern point of an equilateral triangle, with mag. +5.7 HIP 61658 and mag. +6.3 HIP 61637 as the western 'base'. Fortunately, NGC 4636 is a bit easier to identify, being listed at mag. +9.6 and with a diameter around 1.5 arcminutes. It stands out in a 150mm scope, a fuzzy glow with a faint star-like nucleus. A larger instrument shows a similar, albeit brighter, view. Larger apertures help to emphasise how the inner halo brightens towards the stellar core. ☐ **SEEN IT**

This Deep-Sky Tour has been automated ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.

VIRGO

Auva
δ

Porrima
γ

Zaniah
η

HIP 61637
HIP 61428
HIP 61658
HIP 61091
HIP 61252
HIP 61240
HIP 61711
HIP 61358

NGC 4324
NGC 4378
NGC 4580
NGC 4713
NGC 4480
NGC 4412
M61
NGC 4586
NGC 4496A
NGC 4457
NGC 4765
NGC 4630
NGC 4808
NGC 4420
NGC 4527
NGC 4665
NGC 4701
NGC 4179
NGC 4636
NGC 4536
PGC 41121
NGC 4643
NGC 4581
NGC 4900
NGC 4772
NGC 4385
NGC 4517A
NGC 4517
NGC 4845
NGC 4771
NGC 4999
NGC 4632
NGC 4592
NGC 4666
NGC 4653
NGC 4904
NGC 4454
NGC 4753
NGC 4348
NGC 4684
NGC 4691
NGC 4546

13h00m
12h30m
+5°
0°
-5°

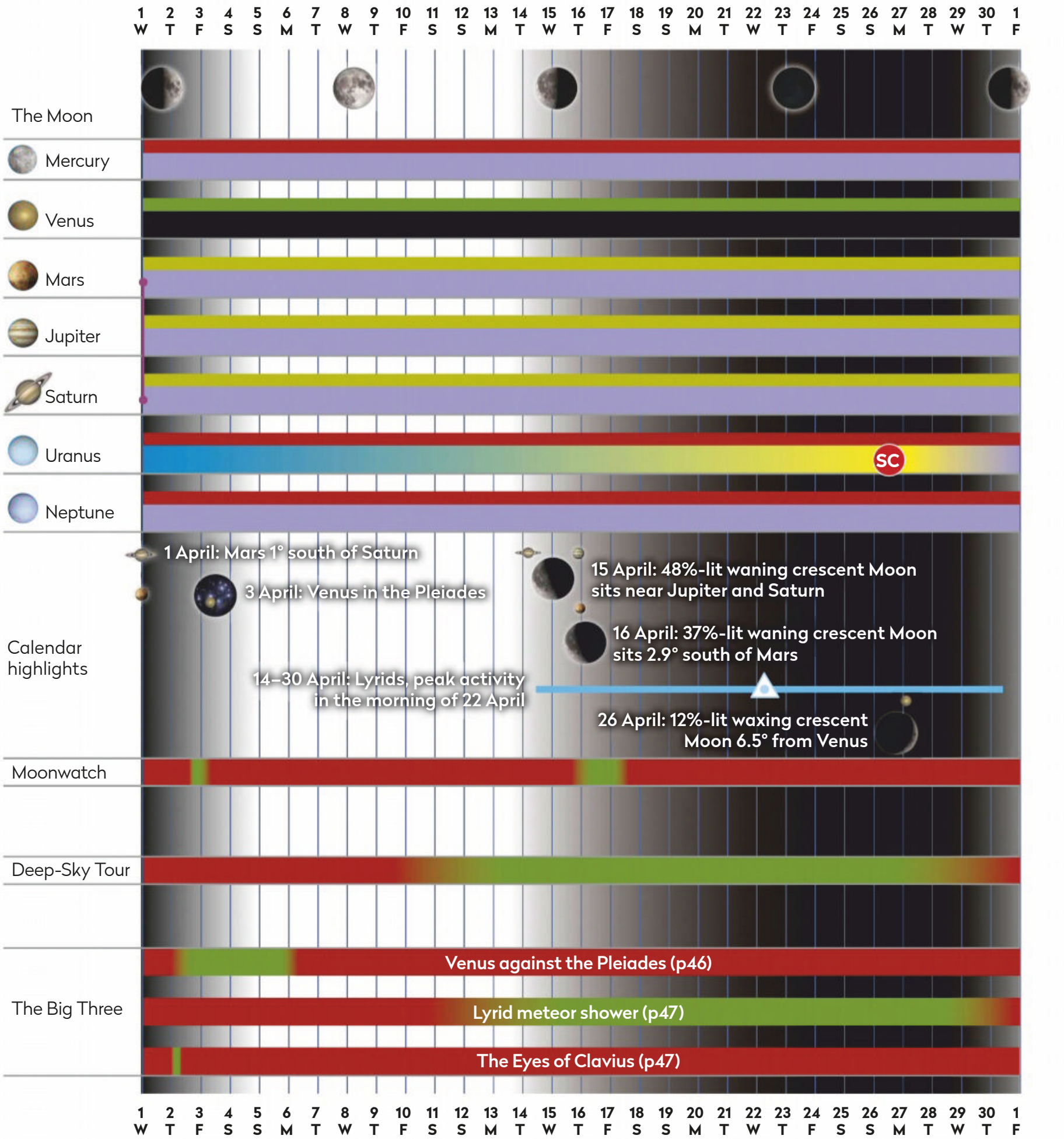
Equator
Ecliptic
Ecliptic

N
E
S
W
2°
1°
16

1
2
3
4
5
6

AT A GLANCE

How the Sky Guide events will appear in April



KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)

SC Superior conjunction

OP Planet at opposition

Meteor radiant peak

Planets in conjunction

Full Moon

First quarter

Last quarter

New Moon

CHART BY PETE LAWRENCE

WE ARE THE DISCOVERERS... WHO GAZE UP INTO THE MOONLIGHT AND FOLLOW THE STARS OF THE DISTANT PAST

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Hubble's legacy: THE SEARCH FOR DARK ENERGY

Over 20 years ago, Hubble helped uncover a strange force driving the Universe apart – dark energy. Govert Schilling investigates a new experiment trying to map out its effect

MARK GARLICK

When the Hubble Space Telescope was launched, 30 years ago this month, no one had ever heard about dark energy. But, in part thanks to Hubble, astronomers have come to realise that we live in an accelerating Universe, in which empty space is expanding ever faster and faster, thanks to this mysterious dark ingredient. This spring, a unique instrument mounted on a venerable telescope in Arizona has started compiling the most detailed 3D-map of the cosmos ever. The goal is to further our understanding of the expansion history of the Universe, and – hopefully – to uncover the true nature of dark energy.

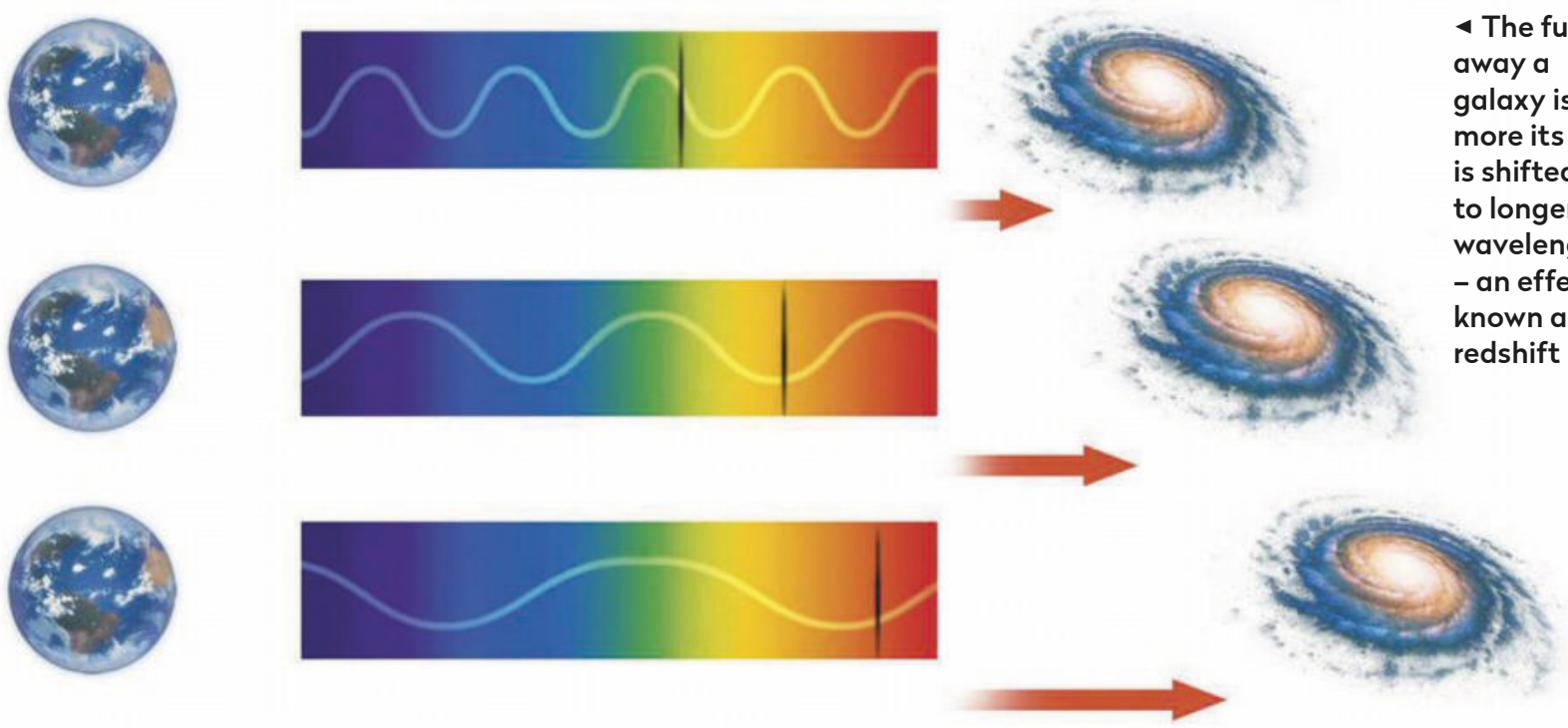
As physicists understand it, dark energy is a property of empty space. Like some sort of anti-gravity, it pushes empty space away from itself, accelerating the expansion that started 13.8 billion years ago with the Big Bang, and creating ever more space in the process. More space means more dark energy, so the effect is self-reinforcing. The discovery of the accelerating expansion of the Universe, by two competing teams of astronomers in 1998, was awarded the 2011 Nobel Prize in Physics. But after two decades of additional research, the true nature of dark energy is still a complete mystery.

▲ **New purpose: the old Mayall Telescope at Arizona's Kitt Peak is being used by DESI**

Stretching the rules

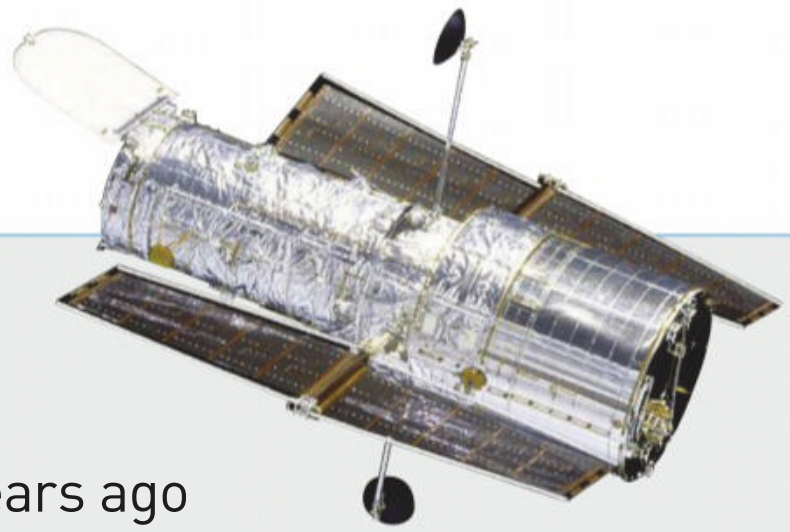
But how do you discover that the present-day Universe is expanding faster than it did one or two billion years ago? The trick is to study galaxies a couple of lightyears away. The light of these distant galaxies arrives on Earth with a longer (redder) wavelength, because the space it's been travelling through has been expanding, stretching the light along with it. Galaxy redshifts therefore provide you with their light travel times. If you also know their corresponding distances, it becomes possible to reconstruct the cosmic expansion history.

Back in 1998, teams led by astronomers Saul Perlmutter, Brian Schmidt and Adam Riess used a specific type of supernova explosion to gauge



◄ **The further away a galaxy is, the more its light is shifted to longer wavelengths – an effect known as redshift**

INGA SPENCE/ALAMY STOCK PHOTO, MARK GARLICK, NASA/ESA/R. WINDHORST/S. COHEN/M. MECHTLEY AND M. RUTKOWSKI (ARIZONA STATE UNIVERSITY/TEMPE), R. O'CONNELL (UNIVERSITY OF VIRGINIA) P. MCCARTHY (CARNEGIE OBSERVATORIES) N. HATHI (UNIVERSITY OF CALIFORNIA/RIVERSIDE), R. RYAN (UNIVERSITY OF CALIFORNIA, DAVIS) H. YAN (OHIO STATE UNIVERSITY) AND A. KOEKEMOER (SPACE TELESCOPE SCIENCE INSTITUTE)



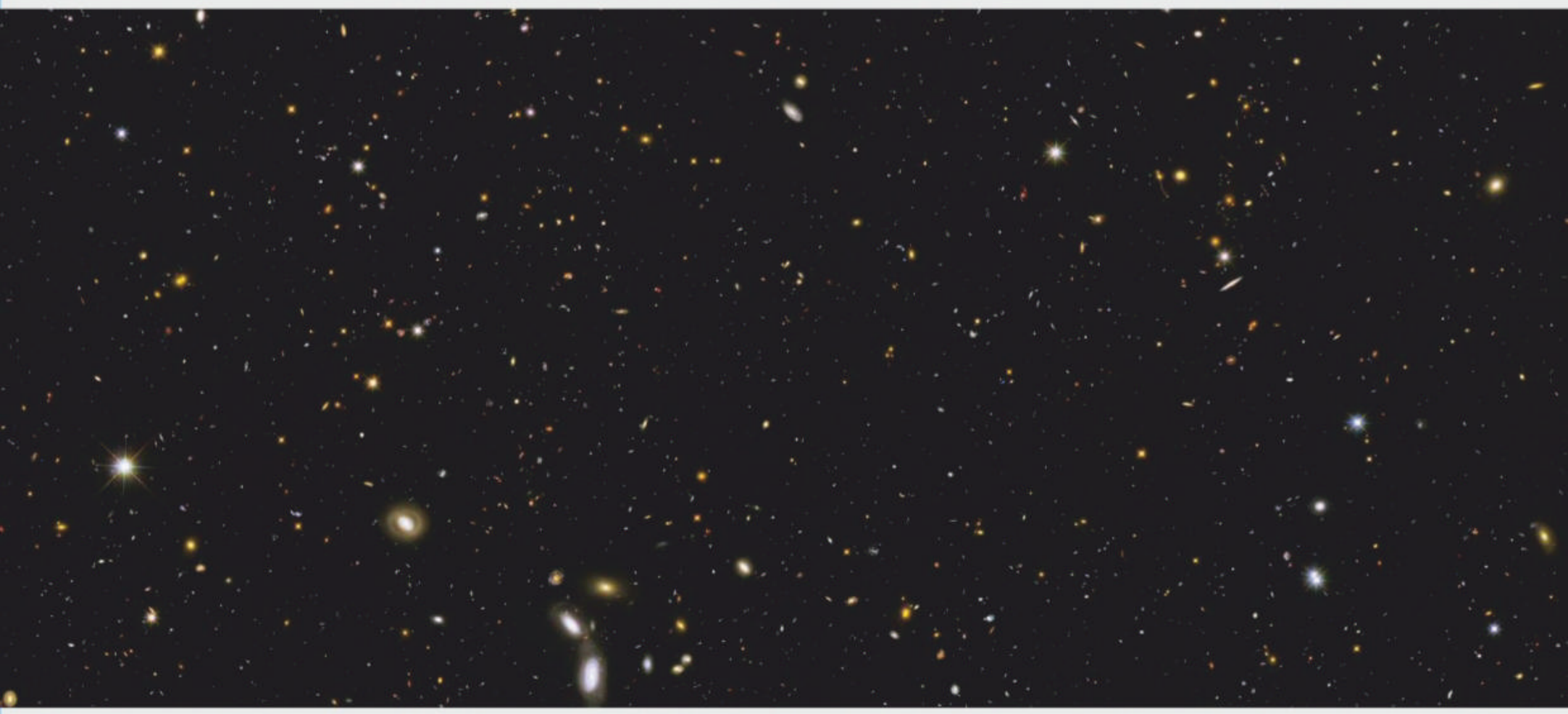
Hubble and dark energy

The quest to find dark energy began over 20 years ago

The accelerating expansion of the Universe was discovered in 1998 by studying supernovae in distant galaxies. The initial supernova observations were carried out by telescopes on the ground. However, to learn more about the expansion history of the Universe and the evolving role of dark energy, we want to study supernovas at a wide range of distances, and the most remote ones are hard to observe with ground-based telescopes.

That's where the Hubble Space Telescope played a decisive role. As soon as a distant supernova was discovered from the ground, Hubble would observe it in much more detail. Moreover, through repeated observations of a large swathe of sky (known as the GOODS field, for Great Observatories Origins Deep Survey), Hubble discovered dozens of extremely distant supernovas on its own.

Thanks to these high-precision observations from Hubble, astronomers became convinced that the original 1998 claim of an accelerating expansion was real. Apparently, some mysterious force is pushing empty space away from itself. The true nature of this dark energy is still very much a matter of debate. Hubble helped frame the question; whether or not it will also help to provide the answer, only time will tell.



▲ **Hubble has discovered many distant supernovas by taking repeated images in the GOODS field (Great Observatories Origins Deep Survey)**

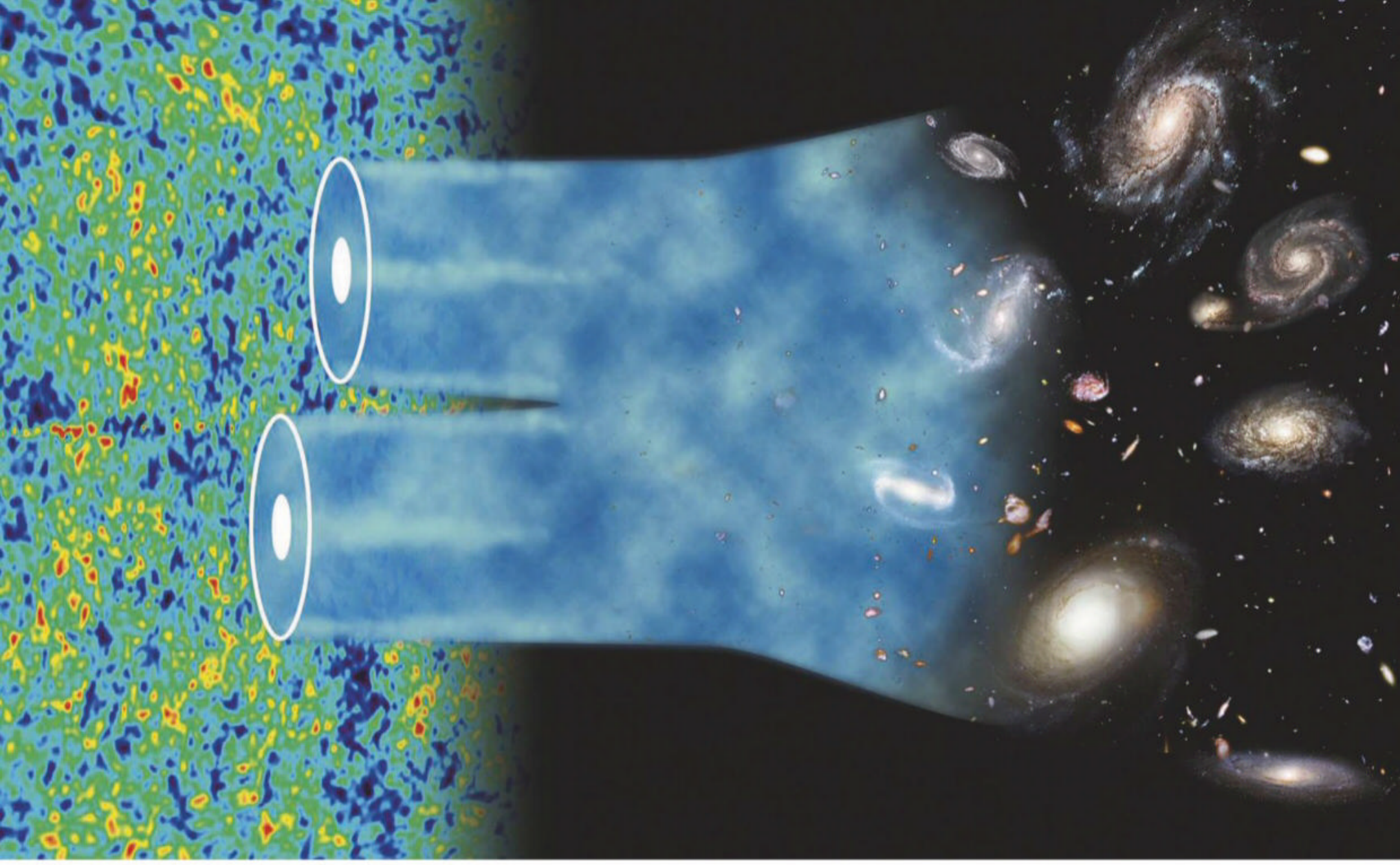
distances. These Type Ia supernovae have well-known luminosities and by comparing those to their observed apparent brightness in the sky, it becomes possible to derive their distances. The Hubble Space Telescope greatly added to this work by discovering and measuring dozens of extremely remote supernovae. However, supernovae are difficult to study as they are so far away and cannot be summoned at will, so astronomers can only study where they happen to appear.

If astronomers really want to understand this mysterious effect, then they need a global map to track how the Universe's acceleration changed over time – not just over the last few billion years, but right back to the Big Bang.

That's where the new instrument comes in. Called DESI (for Dark Energy Spectroscopic Instrument), it uses a very different cosmic yardstick that can be studied throughout the observable Universe. All you need to do is create a detailed 3D map of tens of millions of galaxies. And that's exactly what DESI's job is over the next five years, using the light-gathering power of the old 4m Mayall Telescope at Kitt Peak National Observatory (KPNO) in southern Arizona. 'DESI is giving the 47-year-old telescope a new lease of life,' says KPNO telescope scientist Dick Joyce.

Cosmic scaffolding

It will do this by looking for something called baryon acoustic oscillations (BAO). Right after the Big Bang, sound waves propagated through the hot, dense primordial soup, powered by energetic radiation that was still strongly interacting with the electrically charged plasma. But, explains DESI co-spokesperson ▸



▲ **The study of baryon acoustic oscillations (BAOs) reveals the distribution of the early Universe imprinted in more modern galaxies**

▸ Daniel Eisenstein of Harvard University, after some 380,000 years, neutral atoms formed, and the Universe became transparent. Radiation no longer pushed matter around, and the sound wave pattern became 'frozen in'. When slightly denser regions subsequently started to attract more and more matter, galaxies preferentially formed along this (expanding) cosmic scaffolding.

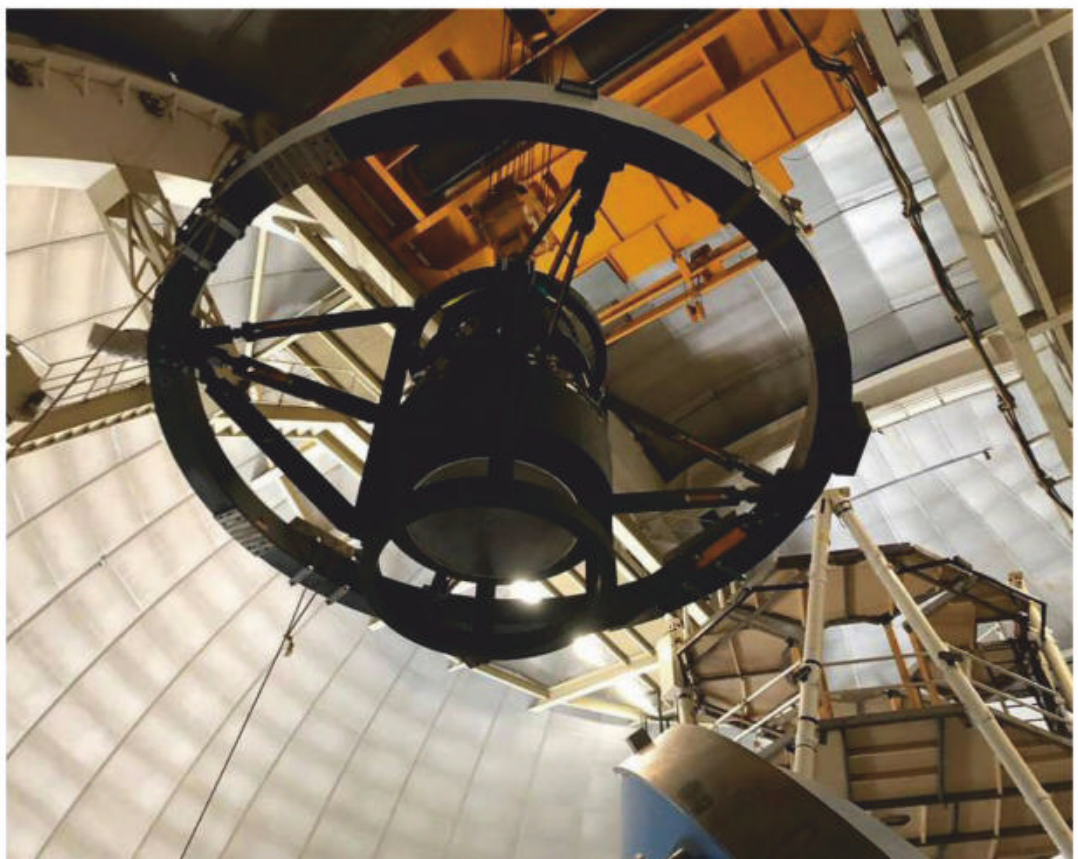
The end result is that the current distribution of galaxies in the Universe is not completely random. 'The effect is much too small to detect by eye,' says Eisenstein, 'but by statistically studying millions of galaxies, it becomes evident.' These fluctuations are BAO. As the pattern changes over time, they can be used to gauge cosmic distances, which can then be compared to redshift measurements to disentangle the expansion history of the Universe and the effects of dark energy.

Using the 2.5m Sloan Digital Sky Survey telescope in New Mexico, Eisenstein and his colleagues have already produced a 3D-map of over 1.5 million galaxies that clearly showed the BAO signal. Their BOSS programme (for Baryon Oscillation Spectroscopic Survey) was completed in 2014. However, it was a slow and cumbersome process. For each new exposure, a thousand optical fibres had to be manually positioned on a custom-made focal plane plate, in which holes had been drilled at specific positions to catch the light of the many galaxies in the field of view. As a result, at most three exposures could be made on any clear night.

KPNO's Dick Joyce calls DESI a major step forward. It could even be described as BOSS on steroids. Mounted on a much larger telescope, it uses 10 sensitive spectrographs, each of which can dissect the light of 500 galaxies at once. Most importantly, the 5,000 optical fibres that feed the spectrographs are positioned robotically within just two or three minutes, during the time the telescope slews to a new field. On a clear night, between 20 and 30 20-minute exposures can be made, yielding 10 terabytes of raw observational data.

Size matters

To achieve a large 3.2° field of view (as wide as six full Moons), the Mayall Telescope has been outfitted with a custom-made corrector (pictured, below) – a 3-tonne, barrel-shaped assembly of six lenses, the largest of which measures 1.1m in diameter. Like a giant pizza, the 0.8m-diameter focal plane of the telescope is divided into 10 wedges with 500 optical fibres each. In total, a whopping 240km of optical fibre guides the light of thousands of galaxies in the field of view to the sensitive spectrographs. Before being spread out into a detailed spectrum, the light



▼ **On the rise: DESI's corrector joins the Mayall Telescope at its Kitt Peak home in 2018**

PAUL WOOTTON, DAVID SPRAYBERRY/NOAO/AURA, AGSANDREW/ISTOCK/GETTY IMAGES

Govert Schilling is the author of *Ripples in Spacetime: Einstein, Gravitational Waves and the Future of Astronomy*

is split into three broad wavelength bands: blue, red and infrared.

To prepare for the DESI project, telescopes at Kitt Peak and Cerro Tololo (Chile) have carried out large photographic sky surveys over the past years. These have been combined into the DESI Legacy Imaging Surveys project, which is freely available on **www.legacysurvey.org**. On the basis of this vast collection of deep-sky images, in three colour bands, project scientists have selected the galaxies and quasars (the luminous cores of very distant galaxies) that will be spectroscopically observed by DESI.

According to Eisenstein, DESI is the next big step in the study of the large-scale structure of the Universe, and of BAOs in particular. It will map one third of the celestial sky (14,000 square degrees), and collect spectra for 35 million galaxies and 2.4 million quasars, out to distances of 11 billion lightyears. The resulting 3D-map of the Universe is by far the largest ever made. And by studying the characteristic size of the BAOs at various redshifts, astronomers will be able to reconstruct the expansion history of the Universe and the evolving role of dark energy.

First light for DESI was achieved on 22 October 2019. After a commissioning phase, the survey is now in full swing. 'Until 2025, the Mayall Telescope is not going to do anything else,' says Joyce.

Of course, the wealth of spectroscopic data that DESI is going to yield will benefit many research topics beyond the mapping of baryon acoustic oscillations. Galaxy redshifts also provide information on proper motions, and thus on the distribution of dark matter in groups and clusters. Knowing precise distances to galaxies makes it possible to better interpret their observed characteristics. Quasar spectra contain information on intervening clouds of intergalactic hydrogen. Evolutionary models of galaxies – and of the whole Universe – will be put to test. Finally, DESI will also study individual stars in our own Galaxy, the Milky Way.

However, the main goal of the new survey is to solve the riddle of dark energy – that mysterious ingredient that constitutes over 70 per cent of the total mass-energy content of the Universe. Discovering exactly when and how the expansion of the Universe started to accelerate, and whether or not dark energy is evolving over time, may help physicists to understand its true nature. It's an answer science has been chasing for over two decades. Hopefully, DESI will be able to provide it.

Does dark energy actually exist?

Not everyone is convinced the Universe is accelerating

Ever since it was first reported, the idea of an accelerating universe – the main motivation for believing in the existence of dark energy – has encountered scepticism and disbelief among a minority of astronomers. They reasoned, for instance, that intervening dust would make a supernova appear dimmer than it really is. Subsequent research has allowed astronomers to work around these issues but not everyone is convinced.

Last December, a team of astronomers led by Young-Wook Lee of Yonsei University in Seoul, Korea, claimed that dark energy does not exist at all. According to their observations of a small sample of distant Type Ia supernovae, these stellar explosions are fainter in younger galaxies than in older ones. If you take that effect into account, all evidence for an accelerating expansion of the Universe vanishes, according to the team in a paper to be published in *The Astrophysical Journal*.

Most astrophysicists and cosmologists are unimpressed by the arguments of Lee's team. Other studies, using larger samples, have failed to show up this relation between supernova luminosities and galaxy ages. Moreover, there are other indications for the existence of dark energy apart from supernovae. It looks like dark energy is here to stay.

Could intervening dust be responsible for the differing brightnesses of supernovae?

You'll be surprised how little experience you need to observe meteors

Observing METEOR SHOWERS: the next step

With the Lyrids meteor shower reaching its peak under a new Moon this month, now's the time to step up your observing with **Pete Lawrence**'s practical guide

Observing meteors is an interesting, albeit – with both the weather and the Moon to contend with – a sometimes frustrating pastime. In their most basic form, meteor watches are pretty easy to carry out, requiring nothing more than a pair of eyes and something to record your results with. As with all scientific recordings, there are guidelines to follow. Getting this right will elevate your observations and help advance our common knowledge of how specific meteor showers work. Best of all, it doesn't take a lot of effort to get to this level and the resulting observations may help predict future meteor activity.

Meteor observing: the basics

Familiarise yourself with how meteors appear in the night sky

▲ **Trains or trails? Get to know the different parts of a meteor and how these visitors to our atmosphere behave in the night sky**

What is a meteor?

The name meteor describes the phenomenon that occurs when a small particle – a meteoroid – enters Earth's atmosphere and vaporises. From the ground, the swift moving path of light that results is what's known as a meteor trail. An average trail is produced by a meteoroid similar in size to a grain of sand.

Larger meteoroids will produce bright trails, and a trail brighter than mag. –4 (similar to Venus) is known as a fireball. Bright trails are often followed by a glowing column of ionised gas called a meteor train, which fades over time. Persistent trains may last for many seconds, becoming distorted by high altitude atmospheric winds.

What is a meteor shower?

Meteor showers are typically associated with comets, although a handful are linked with asteroids. As a comet orbits the Sun, it releases dust. Over many returns, dust spreads around the orbit. Earth passes through numerous dust streams annually and, when this happens, the number of trails seen increases. Peak activity occurs when we pass through the densest part of the stream. Perspective causes the incoming trails to emanate from a small area called the shower radiant, which slowly moves over the duration of the shower. The constellation in which peak activity occurs gives its name to the shower. For example, the Perseids show peak activity when the radiant is in Perseus.

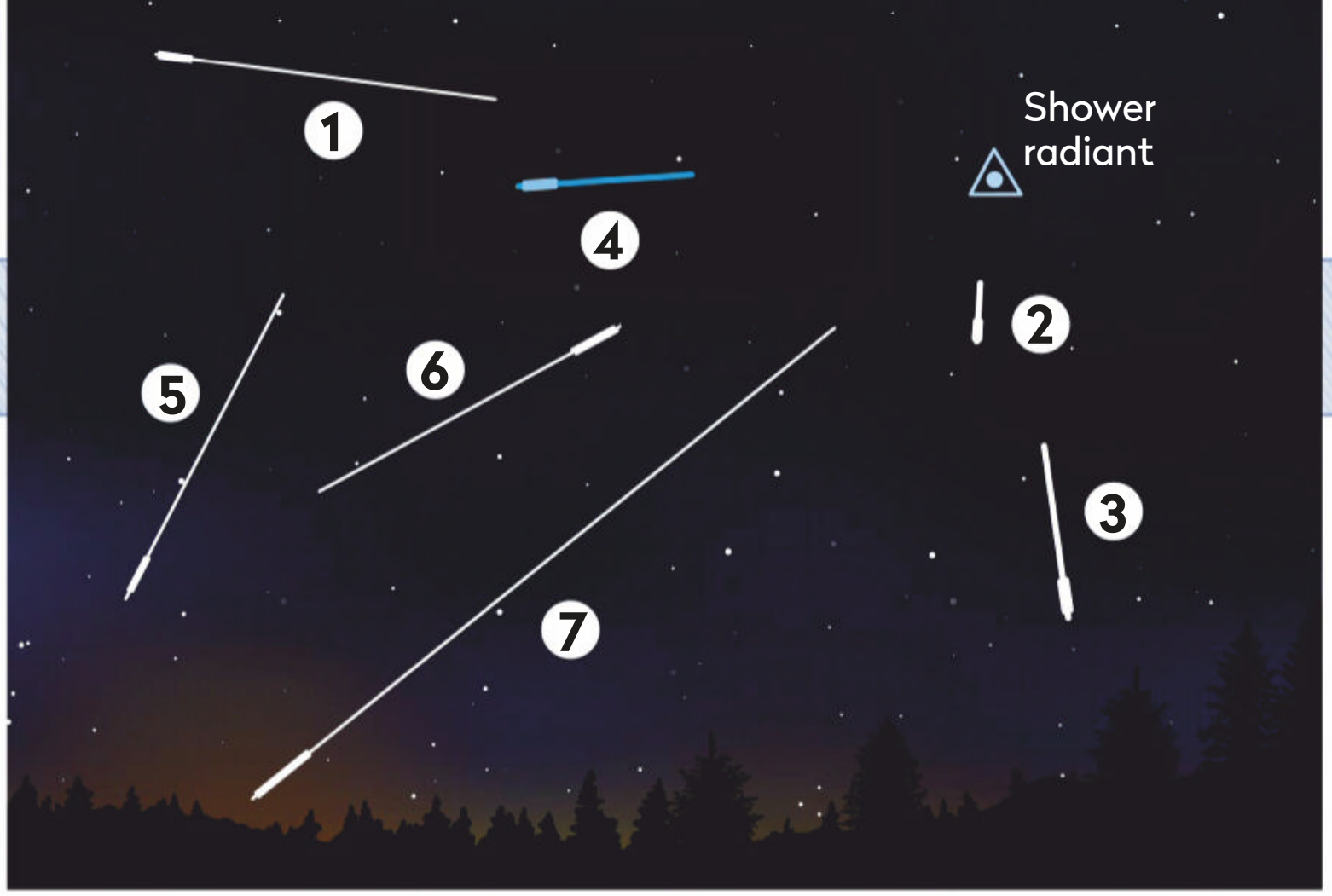
▲ **A sense of perspective: a radiant is where the meteor shower – for example, the Perseids – appears to originate as seen from Earth**

ALL PICTURES: PETE LAWRENCE

Identifying shower meteors

Not every trail will belong to a currently active shower. Multiple showers may have overlapping activity and random or sporadic meteors may occur at any time.

Various checks can be applied, the most important of which is whether a trail appears to come from the shower's radiant. If this isn't the case, it's definitely not a shower meteor. Trail lengths also vary with distance from the radiant: those starting close appear short due to perspective. The trails' apparent ▸



◄ Identifying meteor showers – a spotter's guide:

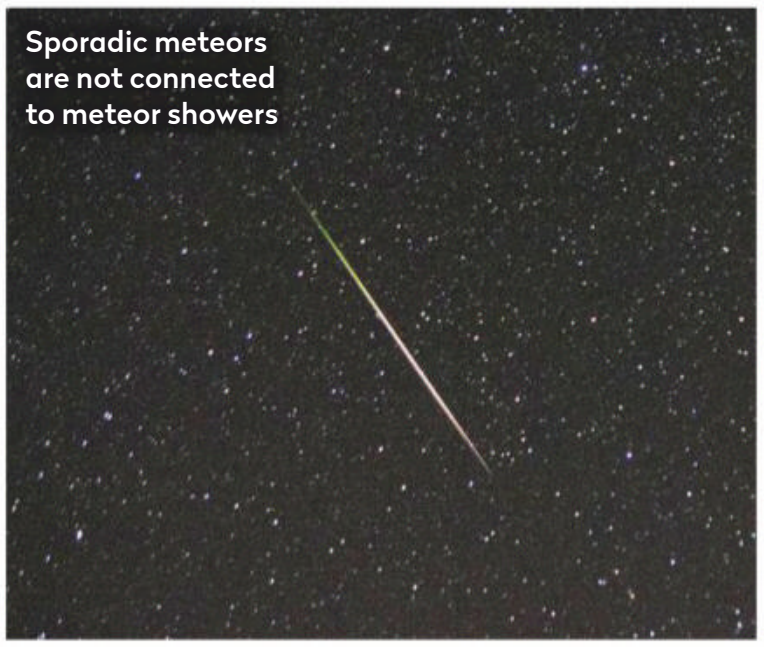
1-3. Shower trails
4. Non-shower trail; wrong colour
5. Non-shower trail; doesn't originate from the radiant
6. Non-shower trail; travelling in the wrong direction
7. Non-shower trail; too long for it's proximity to the radiant

▸ length grows up to 90° from the radiant, after which it shortens again. Trails further than 90° away start to converge to the shower's anti-radiant. Long trails starting near the radiant are statistically unlikely to belong to a shower.

Trickier checks concern colour and speed. Colour, visible in brighter events or in photographs, will often be characteristic for a specific shower. Similarly, trail speed varies between showers: a fast trail among a slow shower is unlikely to belong.

What is a sporadic meteor?

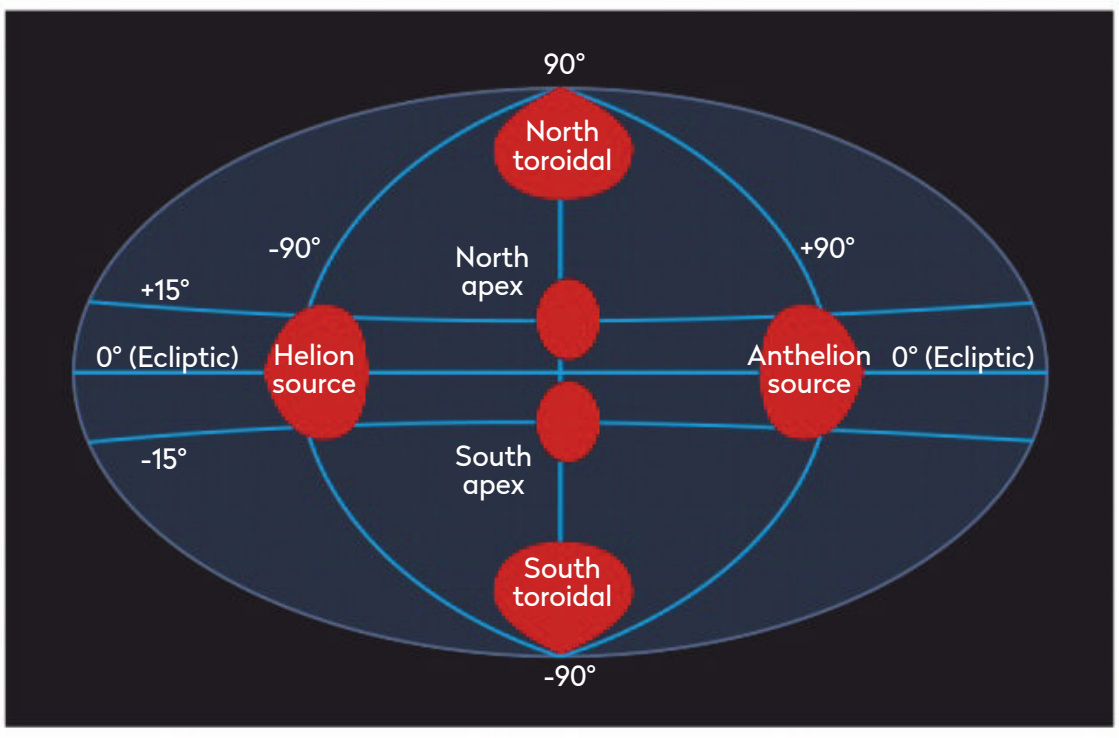
Random meteors not associated with a particular shower may be seen at any time without warning. Known collectively as sporadic meteors (pictured, right), they can appear to come from any direction. Although sporadic meteors don't belong to a cometary stream, many are related in terms of their source area in the sky.


Sporadic meteors are not connected to meteor showers

Sporadic meteor sources

Sporadic meteors tend to originate from one of six sources: helion, antihelion, north apex, south apex, north toroidal and south toroidal (see illustration, below). The helion source is close to the Sun, producing meteors that aren't likely to be seen. The north and south toroidal sources arise from debris in highly inclined ecliptic orbits and aren't well understood. The anthelion source is from particles on low inclination solar orbits. This radiant is 195° of ecliptic longitude east of the Sun, shifted from the expected 180° by Earth's own orbital motion. Like all sporadic sources, it's large at around 20° across. Although up all night, it is best positioned at 02:00 BST (01:00 UT) for the UK.

The two apex sources arise from retrograde particles hitting Earth head-on. The radiants are 15° above and below the ecliptic, 90° west of the Sun. This produces activity in the morning sky. Typically, sporadic sources produce around five meteors per hour.



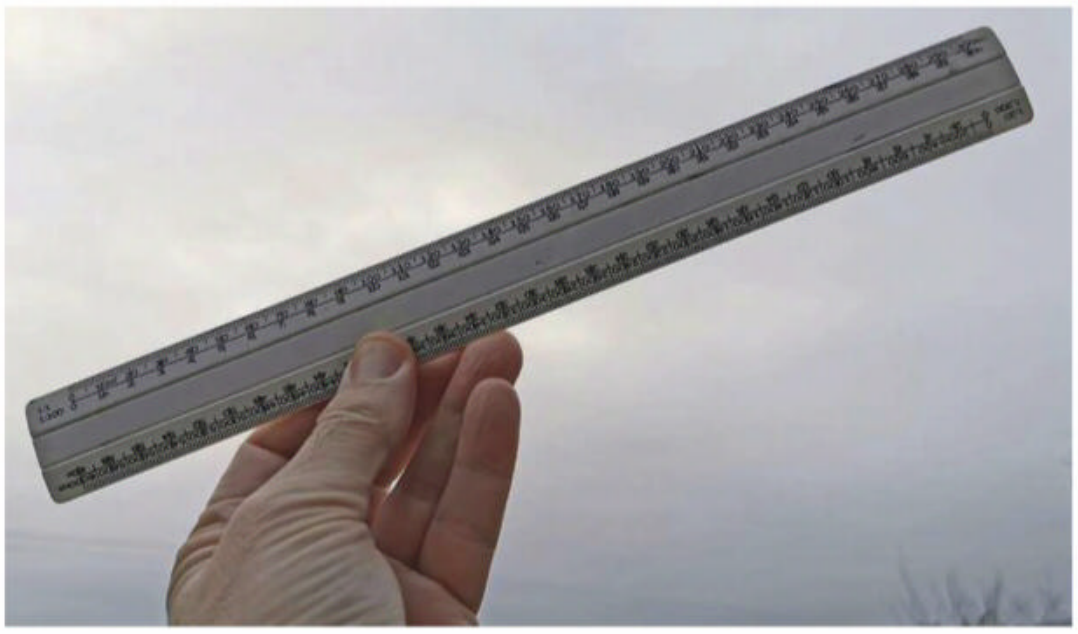
◄ Sporadic meteors originate from one of six sources: helion, antihelion, north and south apex and north and south toroidal

Random meteors may be seen at any time without warning. Known collectively as sporadic meteors they can appear to come from any direction

ALL PICTURES: PETE LAWRENCE

Gear up for meteor watching

Meteor observing equipment doesn't need to be complex



▲ **Straightforward: a ruler is useful for checking that a meteor's trail path goes back to a radiant**

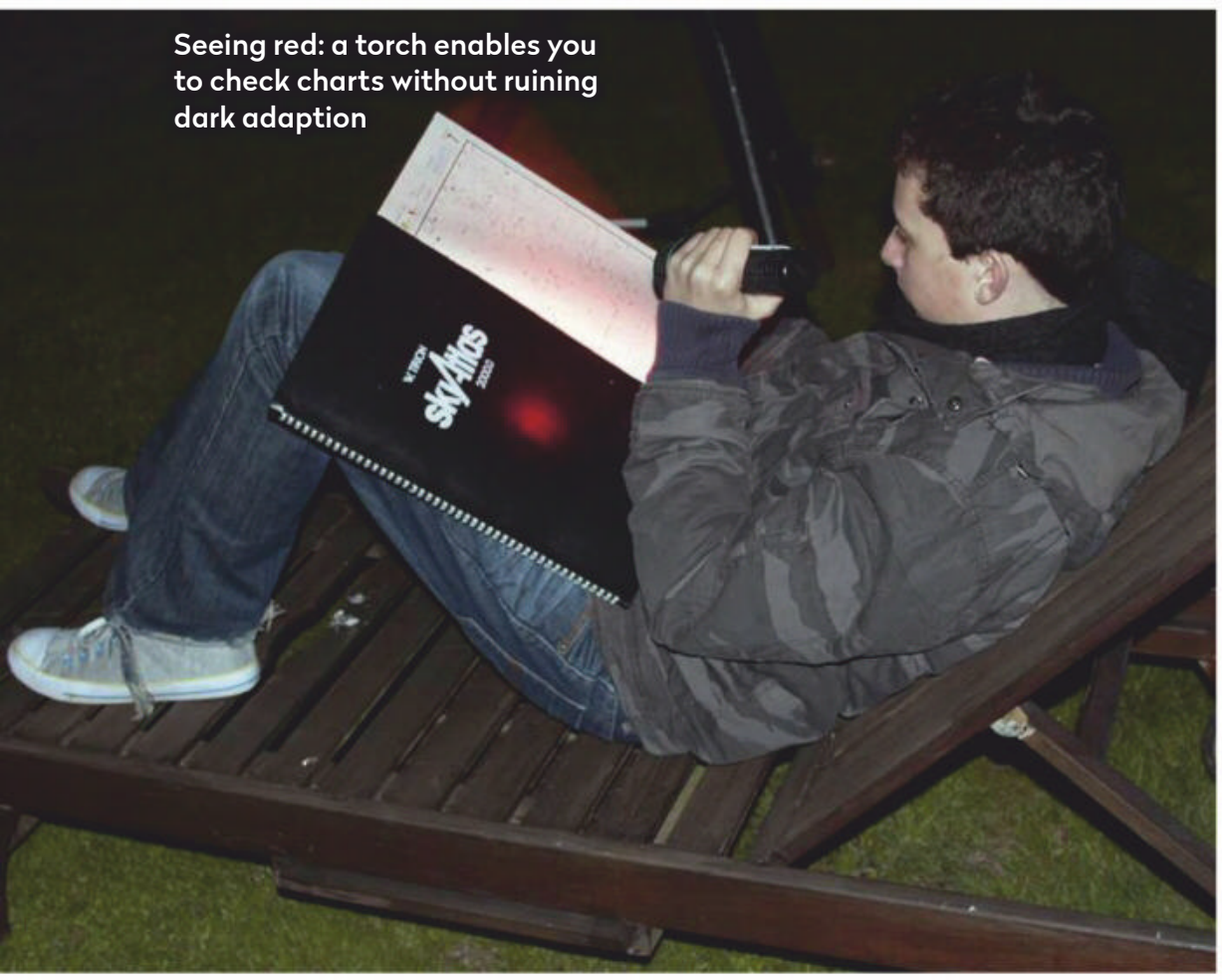
Taking time: an accurate watch will help to keep records

What equipment should you take?

Typically, equipment for observing a meteor shower doesn't need to be elaborate or expensive. A clipboard, dim red torch, accurate watch and a ruler or piece of string will suffice. Meteor reporting forms (see p71) can be downloaded from organisations such as the British Astronomical Association (**britastro.org**), while a dim red torch allows you to look at the form and (unilluminated) watch without ruining your dark adaptation.

If you want to plot trails, widefield charts can be pre-printed prior to the session. These can be generated from many planetarium programs such as the freeware Cartes du Ciel (**www.ap-i.net**). A ruler or piece of string is useful to hold up to the sky to check on the path of the trail, a good way to confirm to yourself that the trail does project back to a shower radiant.

Meteor observing involves statistical recording, but the very act of looking down at a form will affect results because trails may occur while you are looking away from the sky. This can be addressed if you observe in a group and nominate one person to be a central recorder. The rest of the group then arrange themselves like petals of a flower, around the central recorder looking out from the centre. It's the central recorder's job to take down information shouted out by the meteor watchers around them. Alternatively, for solo sessions consider using a voice recorder.



Seeing red: a torch enables you to check charts without ruining dark adaption

What's the best way of staying comfortable?

Comfort is important when observing meteors and using a garden chair, preferably a recliner or sunbed, is recommended. Neck support for long watches is particularly important. Aim to look up at 60°, where the atmospheric thickness isn't great enough to reduce the brightness of trails, but remains sufficiently thick for the number of meteors to remain optimal. It's also important to wrap up warm, even if temperatures are fairly mild at the session's start.

Find a dark location, free from stray light and give your eyes total darkness for at least 20 minutes before you start a watch. Ideally, aim to observe for periods that are multiples of 30 minutes long, say 30, 60 or 90 minutes and pick a direction giving a clear unobstructed view.

Aim to learn at least 10 stars with different visible brightnesses on the night for magnitude estimates (see page 70). The quiet lulls in activity that typically occur during meteor-viewing sessions are useful times to learn the constellations. However, avoid looking down at charts for prolonged periods because this may cause you to miss trails. ▸

Getting to know meteor terms

Everything you need to know about meteor terminology

Introducing Zenithal Hourly Rate (ZHR)

Zenithal Hourly Rate (ZHR) is used to normalise meteor shower rates for comparative purposes and isn't intended to represent expected visual rates.

The term assumes a shower's radiant is directly overhead (at the zenith), a perfectly clear, dark sky with a limiting magnitude of +6.5 and no visual obstructions. Few, if any of these conditions will be met in reality, so the actual number of meteors seen is often significantly lower than the quoted ZHR.

Visual hourly rate (Nv)

An observer's visual hourly rate is the number of shower meteors recorded per hour. If the observing period is less than an hour, the count should be multiplied by 1 over the hour fraction (T). For example, seven shower meteors over 15 minutes (T = 0.25 hours) gives a visual hourly rate of 7 ÷ 0.25 = 28 meteors per hour.

Field of view correction (F)

In an ideal world, you'd be looking at a totally clear sky. In reality, foreground objects or passing clouds get in the way. F corrects for this, calculated as *1 ÷ 1–k*, k representing the fraction of sky lost (0 = clear, 1 = obscured). If a one-third loss of sky is noted, F works out as 1 ÷ 1–0.33 = 1.5.

Population index (r)

A shower's population index (r) indicates the average dimness or brightness of its trails. A value below 2.5 indicates more bright meteors than average, while values below 3.0 indicate the shower has a larger proportion of fainter trails. Values for r can be obtained from various sources such as the International Meteor Organisation (**www.imo.net**).

Limiting magnitude (nelm)

Naked-eye limiting magnitude (nelm) is a way to assess how clear your sky is by monitoring the faintest stars visible using nothing more than your eyes. For typical ZHR calculations, a limiting magnitude of +6.5 is assumed. Moonlight can greatly affect the nelm value. Several magnitudes are lost when a bright Moon is present.

$$ZHR = \frac{Nv \times F \times r^{(6.5-nelm)}}{T \times \sin(Hr)}$$

◄ **The ZHR formula for working out the number of meteors you are actually likely to see**

Radiant altitude (Hr)

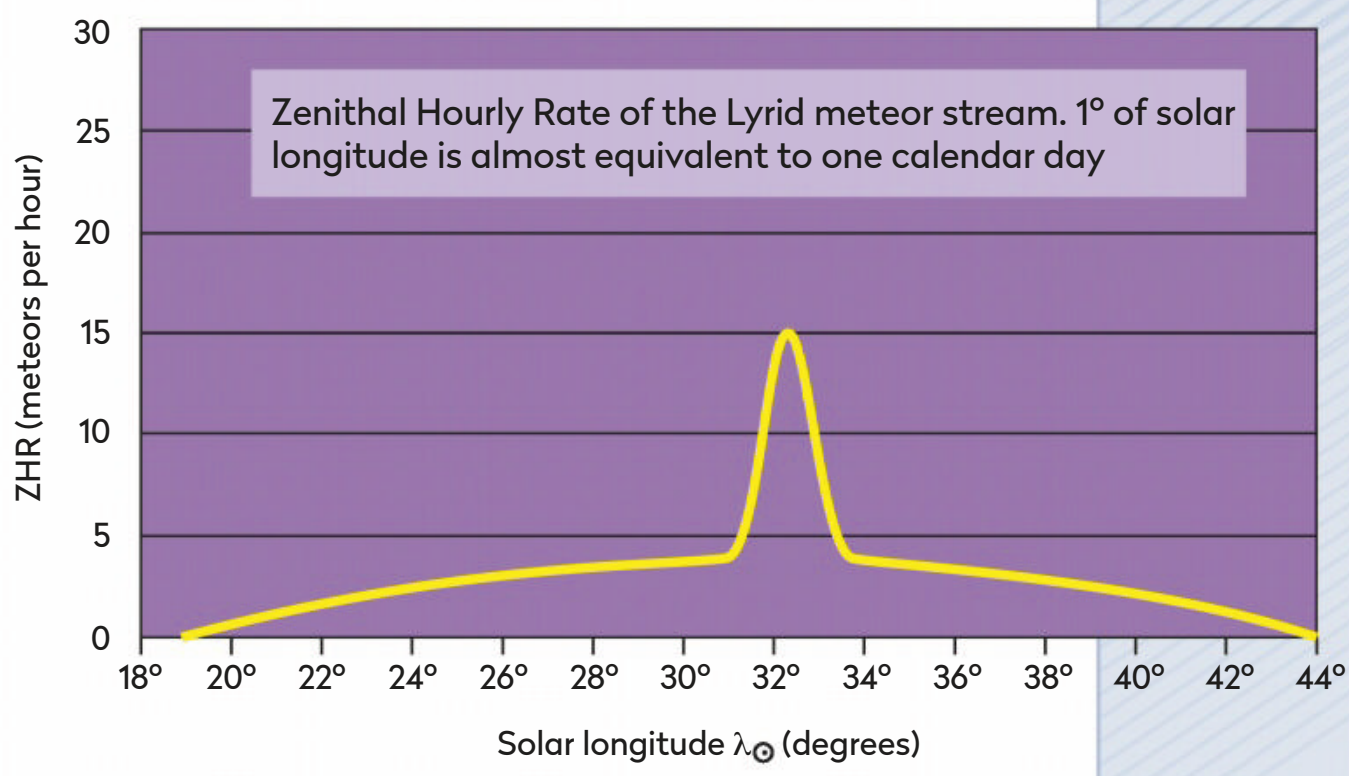
The meteor radiant's height makes a big difference to the number of meteors seen. A low radiant altitude will produce trails that will either occur below the horizon or be seriously dimmed by the thicker layer of atmosphere near to the horizon. The value is measured in degrees.

Rate variation over time

Earth entering the outer edge of a comet's debris stream marks the start of shower activity. The shower's ZHR will be low at this point, increasing to maximum as Earth moves ever deeper into the stream. The peak is related to Earth's orbital position defined by the Sun's ecliptic longitude ($\lambda_{\odot}$). The rise to maximum may result in a narrow, sharp peak lasting only a few hours. Alternatively, if the densest part of the stream is wide, the peak may last for days.

In addition to this natural rate of variation, on any given night the number of meteors seen fluctuates according to radiant altitude and whether you're observing before or after midnight local standard time (UT for the UK). Before midnight, meteoroids play catch up to enter the atmosphere. After midnight, Earth turns so trails are the result of meteoroids colliding head on with the atmosphere. This raises the collision energy, resulting in brighter and, consequently, visually more numerous trails.

Naked-eye limiting magnitude (nelm) is a way to assess how clear your sky is by monitoring the faintest stars visible to just your eyes



▼ **The peak Zenithal Hourly Rate (ZHR) of the Lyrid meteor stream**

PETE LAWRENCE X 2, BRITISH ASTRONOMICAL ASSOCIATION

Filling out your meteor report

Using a BAA form to log your sightings is easy, just follow our checklist

British Astronomical Association
Meteor Section Visual Report

OFFICE USE ONLY | Rec'd | Ack'd

1 Date: 11/12 Aug 2020 | Observer(s): 2 A.N. Observer

Observing site: 3 52 56 19 N, 000 58 50 W | Sheet 1 of 1 4

Correspondence address 5 1 Address Rd, Observington

Observing conditions: 6 Clear but hazy. Lot of mositure in the air. Cloud appeared at end of session.

Stellar limiting magnitude: 7 +5.1

Watch Times: 8 Start: 00:30 | End: 01:00 | Duration: 00:30

Code No.	Time UT	Magnitude	Name Shower or if Sporadic	Constellation(s) in which seen	Train details and time to fade (secs)	Notes
A	B	C	D	E	F	G
001	00:34:07	α Per	Perseid	TAU	---	---
002	00:36:43	α Lyr	Perseid	CYG	2s	Terminal burst
003	00:38:54	−5	Spor	CYG	15s	Slow moving

◄ **Get involved: by downloading a meteor reporting form from the British Astronomical Association (britastro.org) you can help with its national survey**

5 Correspondence address is where you can be contacted if the need should arise.

6 Observing conditions is intended as a general statement of the conditions throughout the watch. Augment with times if conditions vary greatly during the watch period.

7 Stellar limiting magnitude is a record of the faintest star which can be seen overhead. Again, augment with timed values if conditions vary greatly during the watch session.

8 The **Start**, **End** and, for convenience, **Duration** of the watch should also be recorded. Use UT throughout.

How to log each of your sightings

A Code No. is a sequential number used to identify a trail. If you're in a group and performing central recording functions, it's useful to leave a gap of say 5 or 10 between numbers so any trails reported out of sequence can be given the correct number even though they are in the wrong row. The row sequence can later be corrected when the form is formally written up.

B Time UT indicates when the trail was seen. To the nearest minute is acceptable, although recording in higher time resolution is always useful.

C Magnitude can either be a magnitude estimate of the meteor trail or the name of the nearest star of equivalent brightness. The latter tends to remove observer bias. It's useful to have located a number of comparison stars of varying magnitudes before a session for this purpose.

D Name of shower or if sporadic is for the shower name the trail belongs to or whether it's a sporadic meteor.

E Constellation(s) in which seen is used to describe the starting and ending constellation of the trail.

F Train details and time to fade is to record any special qualities about meteor trains. Time to fade records the number of seconds the train takes to become invisible to the naked eye. It's good practice to start counting in seconds in your head after any bright trail, just in case there's a train visible afterwards.

G Notes is used to indicate any peculiarities about the trail. Examples would include 'it exhibited a strong green colour' or 'meteor trail showed a terminal burst at the end'.

Pete Lawrence is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Getting started

1 Date is normally stated as a double-date (say, 13/14 December 2020). This removes any ambiguity as it covers the evening to morning observed.

2 Observer(s) records the name(s) of anyone who contributes to the form.

3 Observing site identifies where you observed from, latitude and longitude being ideal. This can be obtained from a map or an online resource such as Google Earth.

4 Sheet of is used to ensure no loose sheets are missed, for example Sheet 2 of 4.

The fundamentals of astronomy for beginners

EXPLAINER

Asterisms vs constellations

The informal star patterns in the night sky form a game of cosmic dot-to-dot

▲ Shapes in the stars: asterisms (shown in red) can cross constellations, which are in fact regions of sky, not just the main patterns

ALL PICTURES: PETE LAWRENCE

What were the first things you learnt about astronomy, after the names of the planets and the phases of the Moon? It was probably that the groups of stars we see each night are called constellations. That's on the right track, but not entirely true.

People have seen patterns among the stars for as long as there have been people to see them. If you've ever had the chance to be under a deep and disorientating dark sky, it's not hard to imagine what our ancestors saw and spent their nights talking about.

In the Western tradition, it was the third-century BC Greek poet Aratus that first set out a description of 43 constellations, which Ptolemy developed into a list of 48 in the second century AD. The patterns were amended over time, but for the most part lasted until 1922, when the International Astronomical Union (IAU) refined the list, but also made one very important change. They defined constellation borders and, with those borders, defined the modern, official 88 regions that cover the sky.

This means, for example, when we talk about Gemini, Cygnus or Ursa Major, these days we're referring to an entire region of the sky; the stars within are like the constellations' big cities, shining in the distance. This definition wraps each constellation around its stars and is particularly useful for identifying far away galaxies and finding our way back to them.

Making connections

Asterisms, on the other hand, are informal but recognisable star patterns, which can be part of one or more constellations. So while all the stars of the Plough or Big Dipper – perhaps the most famous asterism of all – are within the constellation of Ursa Major, the three stars of the Summer Triangle asterism (see chart, opposite) are each in different constellations: Vega (in Lyra), Altair (Aquila) and Deneb (Cygnus).

The stars you think of as 'Orion' are that constellation's asterism. You can find the Hunter's main asterism, with Betelgeuse at one shoulder and Rigel at a knee, without much trouble throughout autumn, winter and into spring. That group is within a much bigger asterism, the Winter Hexagon – six first-magnitude stars in six constellations: Capella (Auriga), Pollux (Gemini), Procyon (Canis Minor), Sirius (Canis Major), Orion's Rigel and Aldebaran (Taurus).

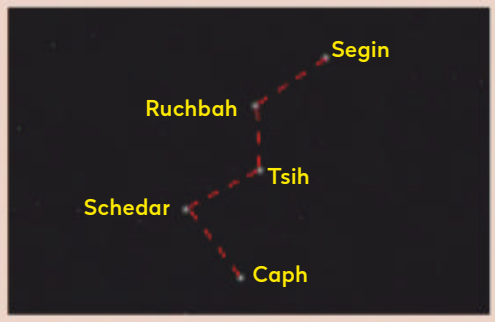
Many think of the three stars in Orion's Belt (Alnitak, Alnilam and Mintaka) as another asterism. His Sword is one too, and if you look closely at its middle star, you'll see it's not a star at all, but the Orion Nebula. Glowing within all that dust is the Trapezium Cluster which, even with a small pair of binoculars, can be seen as an asterism of three or four stars. What you have is a small asterism (Trapezium) located within a bigger one (Orion's Sword), which is itself within Orion's main asterism – and all of these are tied together within the enormous Winter Hexagon asterism.

You can even come up with your own asterisms, maybe 'The Great Office Chair of Corvus', or 'The Perfectly Straight Line of Four Dim Stars Near Cygnus'? Thinking up patterns gives you a chance to find your way around the sky on your own terms. Why not head out and make some up tonight?

Scott Levine is a naked-eye astronomy enthusiast based in New York's Hudson Valley. Read his blog at **scottastronomy.wordpress.com**

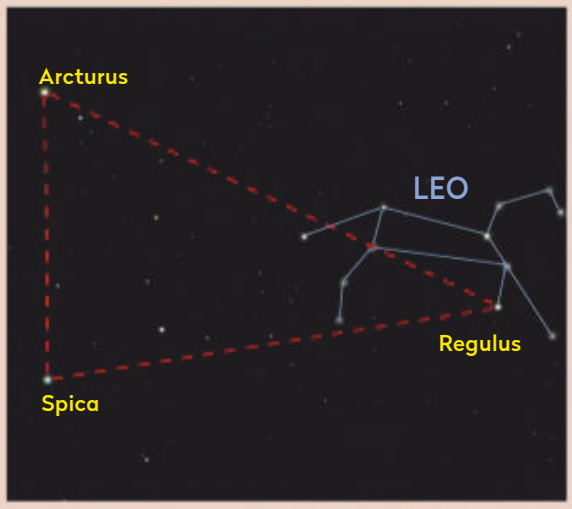
Pinpoint THE PATTERNS

See if you can spot these four famous asterisms as they appear in the night sky throughout the astronomical calendar



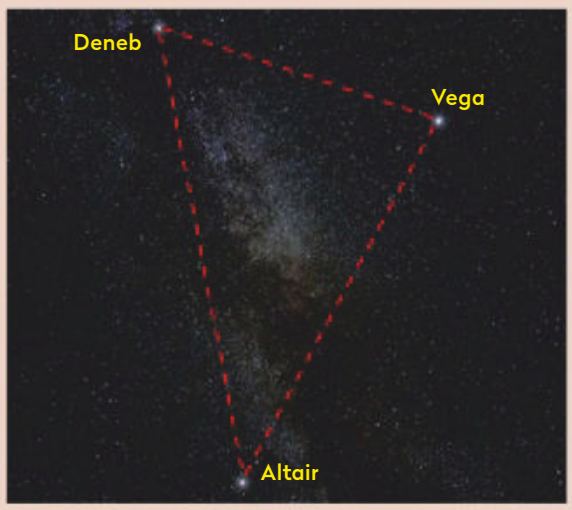
THE PLOUGH AND THE 'W'

The Plough and a 'W' shape formed by Cassiopeia's brightest stars appear to circle around Polaris, the North Star, every night. Use pointer stars Merak and Dubhe at the Plough's front to find Polaris, then continue to Cassiopeia. If the skies are dark enough, you may be able to make out the rest of Ursa Minor's dim stars.



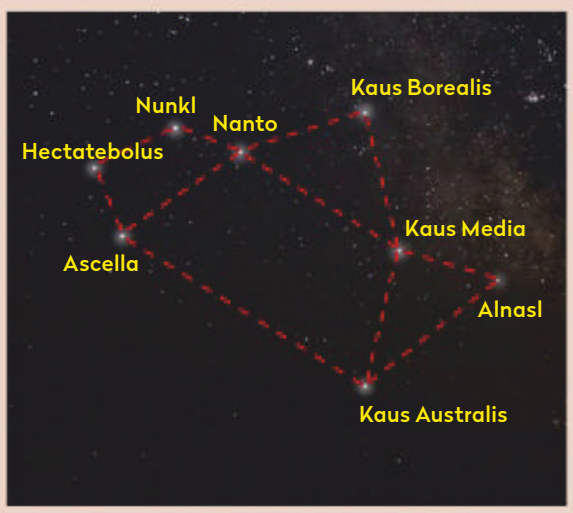
SPRING TRIANGLE

The underappreciated Spring Triangle makes its way into the night sky in February, and by April it's high enough to be a beautiful sight. Though the Triangle is broader than its summer cousin (see below), its corner stars Regulus (in Leo), Arcturus (in Boötes) and Spica (in Virgo) make this Triangle more understated.



SUMMER TRIANGLE

The Summer Triangle of Deneb (brightest star in Cygnus, the Swan), Vega (in Lyra, the Harp) and Altair (in Aquila, the Eagle) appears late in spring. Imagine the two birds soaring overhead after a long summer sunset. Despite the name, the Summer Triangle can still be seen in January.



THE TEAPOT

Sagittarius rides low in the southern sky all summer. Its brightest stars form a famous asterism that looks like a Teapot. If your skies cooperate, you may see what looks like a puff of steam billowing from the Teapot's spout. That's the central part of the Milky Way; the light of countless far-off stars and dust blurred together.

Practical astronomy projects for every level of expertise

DIY ASTRONOMY

Create a customised landscape in Stellarium

How to personalise your view of the night sky in this free planetarium software

▲ **Why not use your own back garden view as a Stellarium landscape?**

Stellarium is a fantastic piece of planetarium software and it's invaluable for helping to plan observing sessions. The program is freely available to download from **https://stellarium.org** and shows you what you can see in the sky on any particular date and time from any location.

The view it gives of the night sky is flexible, with the ability to control displays of stars, planets, labelling and more. As well as the view above you can also alter the view it shows of the horizon, which we'll look at here. With careful tweaking of all the settings it can almost look like the real sky, so much so that some planetarium operators use it to project a view of the night sky across their dome.

Dave Eagle is an astronomer, astrophotographer, planetarium operator and writer

It's useful for seeing what's around on those nights when clouds are hiding the sky, and another great feature is that it enables you to view the sky from other bodies in our Solar System. For example, the Moon.

Changes of scene

So what about the horizon view? When Stellarium runs it automatically places a default graphic of a landscape around the edges of the horizon. The program comes with a number of landscapes pre-installed and available to choose from, which can be useful if you want to experience what other locations have as their horizon. If you use the program to visit the Moon's surface, for example, it makes sense to replace the Earth-like landscape with something a little more suitable. To change it, press F4 and then select the Landscape tab. Within the landscapes available there should be a lunar landscape that you can choose.

If any of the supplied landscapes aren't suitable, there are a number of others that can be downloaded from **https://stellarium.org/en_GB/landscapes.html**. Copy the extracted folders into the same landscape folder of your system and they will be available to use from the Landscape selection menu.

It's all very well having these pre-made landscapes, and they look impressive, but wouldn't it be great to be able to show your own landscape, as a true reflection of your own location? The good news is that this feature is available and is easy to do. You just need some basic computer file and image manipulation skills, along with your own selection of images covering a 360° view of your horizon. You can do the latter with a DSLR or a smartphone. Having your own landscape helps you to plan your observations, as you know what parts of the sky are accessible or are blocked by trees or buildings.

Once your new landscape has been set up, you can add as many as you like, such as famous landmarks or places you've visited. By using Stellarium's Landscape selection tool you'll be able to switch landscapes, whether you wish to see the view from your own location, or if you just feel like a change of scene.

What you'll need

▶ The Stellarium planetarium program: make sure you have the latest version of the software installed.

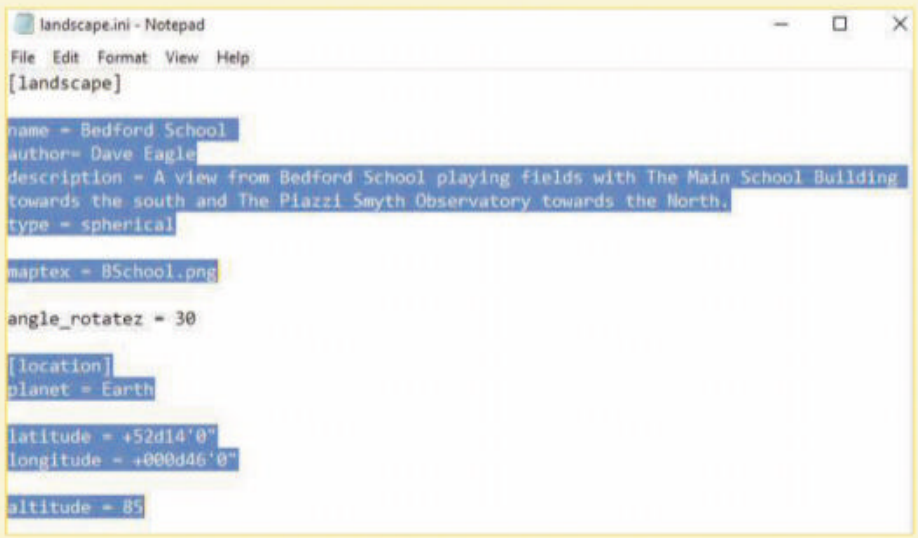
▶ A camera: a DSLR or mobile phone can be used to take the images required for your new landscape. If your phone takes wrap-around landscape images, this may make it easier, depending on the saved file format.

▶ Mosaic-stitching software: Microsoft Image Composite Editor (ICE) is great for stitching mosaics together for your landscape, before using an image-editing program to create the final image.

▶ Image-processing software: any image-processing program can be used such as Adobe Photoshop or Affinity Photo.

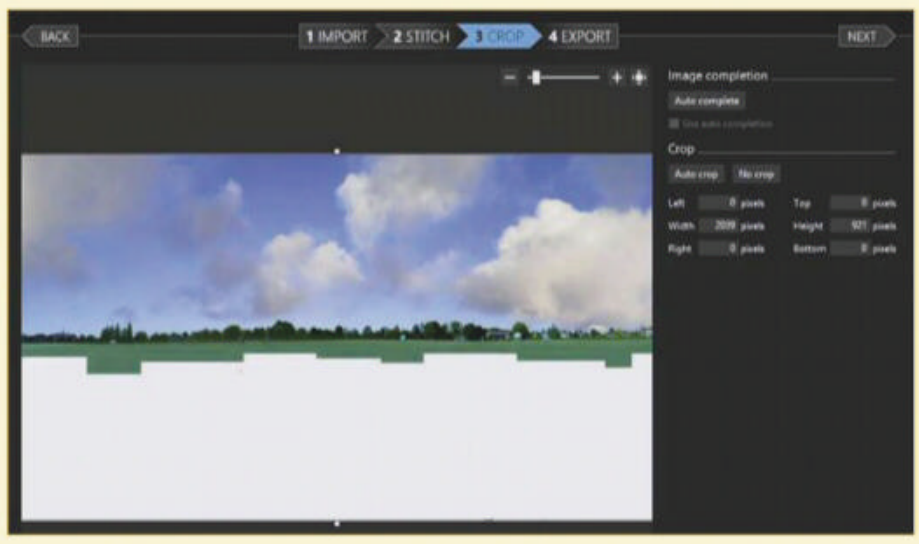
ALL PICTURES: DAVE EAGLE

Step by step



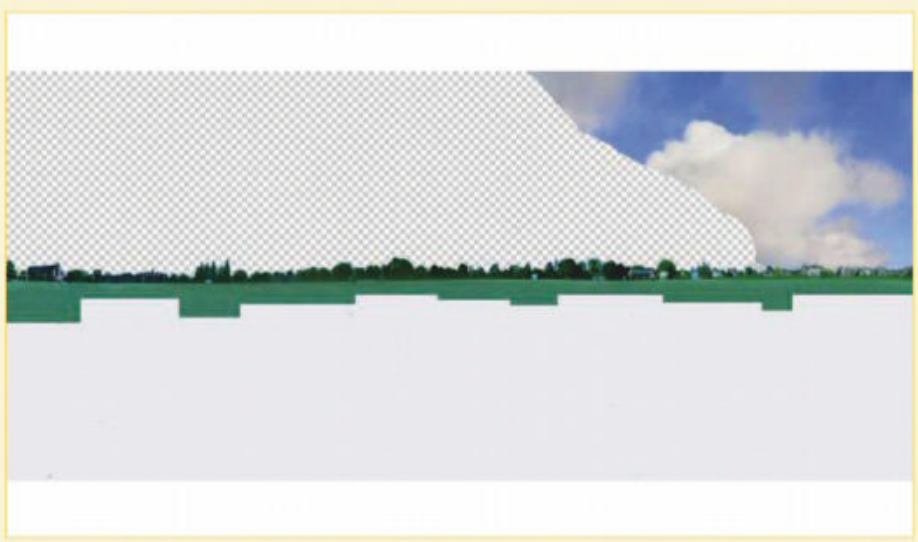
Step 1

Find the Stellarium landscapes folder: C:\Program Files\Stellarium\landscapes\. Copy one of the landscape folders and rename it to match your new landscape. Edit the landscape.ini file using Notepad to match the name and location of your new landscape.



Step 2

Take a set of overlapping images of your location, capturing 360° of horizon, leaving plenty of overlap between them. Use an image mosaic software such as Microsoft Image Composite Editor (ICE) to stitch the images together to create a flat panorama, and save.

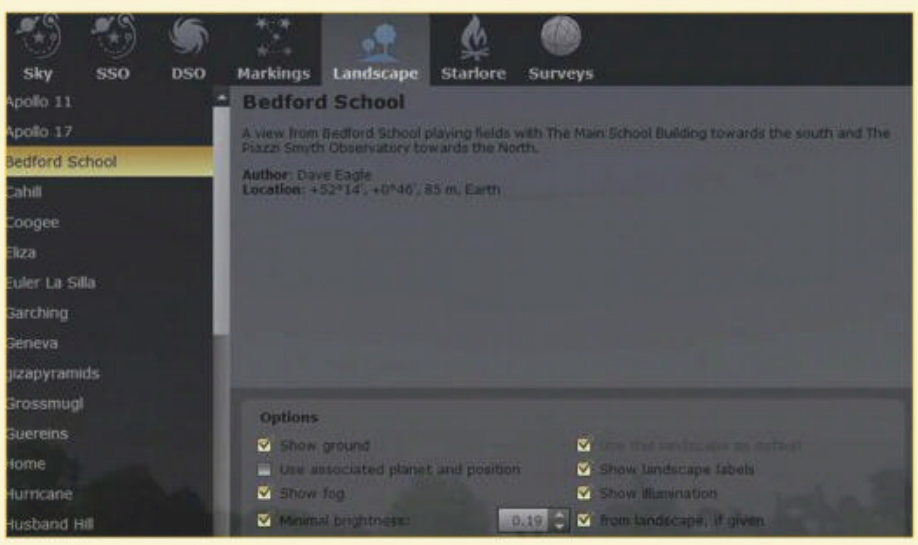


Step 3

Use image-processing software to create an image 2,044 x 1,276 pixels with a transparent background. Open and paste your panorama into a new layer. Use an eraser tool to delete above your horizon to make it transparent so Stellarium's sky can be seen.

Step 4

Use the clone tool to fill all parts of the image below the horizon, but don't flatten the image: save it as a PNG file into your new folder. This will be your 'maptex' file mentioned in the landscape.inf file. Make sure the PNG file name is the same.



Step 5

Open Stellarium. Your new landscape should be accessible by pressing 'F4 (for Sky and Viewing Options menu) > Landscape'. If the graphic of your new horizon is too high or low, you may need to go back and adjust the landscape's vertical position in the PNG image.

Step 6

If the cardinal points of the compass are not orientated correctly to what you see in your view, adjust the value of angle rotatez in the landscape.ini file. This may take a bit of trial and error in order to achieve the correct orientation.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

How spiky can you make Venus appear?

How diffraction effects can enhance your images of our neighbouring bright planet

Venus is an intensely bright planet, the brightest of all the planets seen from Earth. Its light is so intense that it opens up some wonderful opportunities to show some of the physical properties of light in action, such as diffraction.

Diffraction effects can divide the crowd, especially in deep-sky images. The secondary mirror support in Newtonian reflectors creates them naturally, most notably around bright stars. Some people even like them so much that they add them to non-diffraction spiked images using software. A middle ground can be found by adding a diffraction edge to the front of a non-spike creating instrument. The easiest method is to string cotton across the front aperture. Newtonian reflectors and the 'cotton trick' do at least produce natural spikes.

▲ **Dramatic effect: Venus produces spectacular spikes because it's a bright source of light**

From Venus with spikes

The best way to achieve Venusian spikes is to use a camera mounted on a tracking mount. This allows you to extend exposures to show the effect well. A fixed tripod also works, but here you'll need to up the ISO and keep exposure times shorter to avoid the planet trailing.

Diffraction occurs when light passes across an edge. Propagating light waves get bent by the edge and each diffracted wave acts like a spherical propagating light source (Huygens-Fresnel principle). These secondary waves interfere with one another.

A straight edge produces the best diffraction, a curved surface spreads the effect into a pattern which is less obvious. Indeed, specially curved reflector spiders are available which avoid the sharp spikes altogether.

A single straight spider vane has two diffracting edges, one either side. These produce two spikes. A four-vane spider will produce eight spikes with one set of four overlaying the other. This results in four visible spikes. If the vanes are incorrectly twisted, a pattern of four double-spikes is seen.

A traditional camera lens uses blades to narrow or widen the aperture. For a given focal length, changing the apparent diameter of the lens opening affects the lens's focal ratio (f-number). A high f-number means the lens aperture has been stopped down to a small hole. Traditionally in astrophotography we strive to gather as much light as possible and keep f-numbers low. At the lowest f-number the blades are retracted to present a clean circular hole. Although a lens aperture may be thought of as a circular hole, when it's stopped down to a smaller size, the shape is approximated by using straight-edge aperture blades. As such, each blade edge is capable of producing a diffraction spike.

Where Venus is concerned, light gathering isn't much of an issue and we can stop a lens down and still get an image. This increases the intensity of the diffracting edge surfaces and results in a naturally diffraction-spiked image. The quality of the spikes depends on the nature of the aperture blade shapes. Some lenses produce beautiful spikes, others create a blurry mess.

In our Step by Step guide (opposite) we look at how to image Venus with natural diffraction spikes. Whether you love or loathe them, it's interesting to experiment with techniques to see the effects you can create.

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

Recommended equipment: DSLR camera with lens, tripod or preferably a tracking mount

✉ **Send your images to:**
gallery@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

Step by step

STEP 1

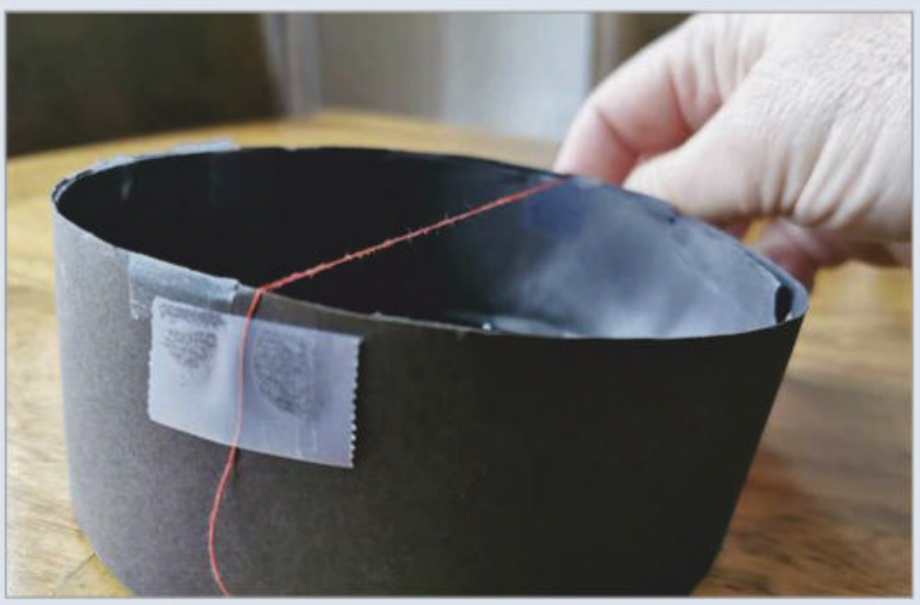
The lens aperture size is determined by its f-number setting. The lower value will vary between lenses but it typically rises to a high value around f/32. For good quality Venus spikes, a setting around f/11 to f/16 works well. A useful tip is to ensure your sensor is clean, as high f-numbers bring any specks present into sharp relief.

STEP 2

For camera setups, a tripod can be used as long as the exposure time is kept short enough to prevent trailing. With a stopped down lens, a high ISO will be required and this will introduce noise, unwanted grainy artefacts that will affect the quality of the spikes. A tracking mount is a more rewarding option, allowing for a longer exposure at lower ISOs.

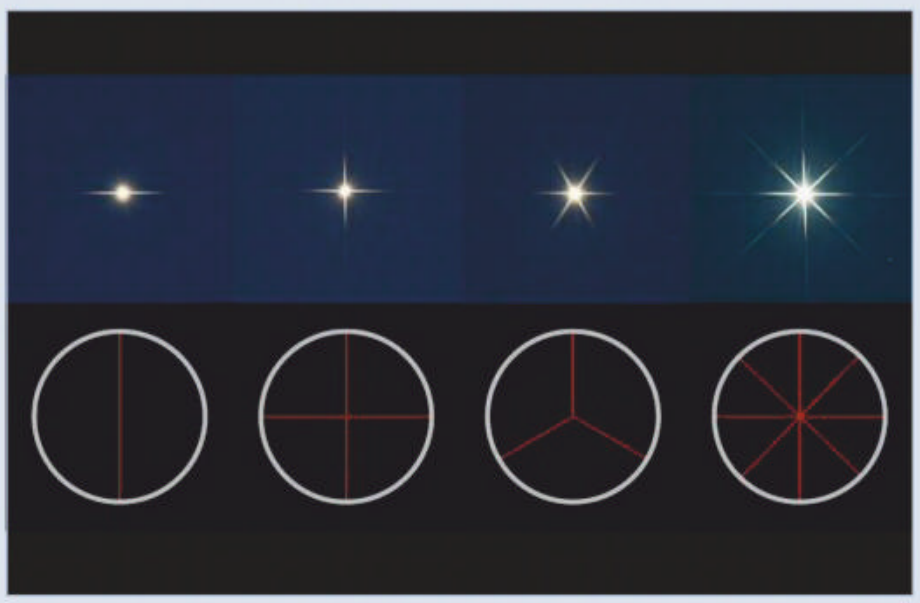
STEP 3

Different lenses use different types of aperture blades. Some are suitable for creating sharp diffraction spikes while others are not. If you have an unsuitable lens you might find the spikes less well defined. The only options are to try a different lens, or fully open the lens aperture and stretch cotton across the lens front (Step 4).



STEP 4

Using a lens or an unobstructed aperture instrument like a refractor, diffraction spikes can be introduced using cotton. The easiest method is to create a card tube to slide over the front of the lens or scope. With the tube in place, cotton can be stretched across the diameter and fixed with tape.



STEP 5

Two threads of cotton at 90° orientation will give two overlapping sets of four spikes. More creativity can be achieved by changing the thread numbers. An arrangement of three threads at 120°-intervals will give six spikes (two per thread), while two sets of 90°-threads rotated by 45° will produce two overlapping sets of eight spikes.

STEP 6

Venus produces the best spikes because it's a bright point source. However, for a really dramatic effect, it's also possible to generate spikes from a larger, non-point source such as the Moon. The Moon will be close to Venus on 25, 26 and 27 April providing an opportunity to achieve this.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Get rid of unwanted colour fringes on star images

Using a chromatic aberration software tool to remove unsightly rings around stars

ALL PICTURES: PAUL MONEY

Refractor telescopes are a popular choice for viewing and imaging deep-sky targets. Relatively inexpensive refractors are 'achromats', so-called because of their achromatic lens, but these often suffer from an effect known as chromatic aberration. This is where the focused light doesn't quite bring all of the colours to the same point, resulting in slight colour-fringing around the stars. Achromats are best used for visual observation, but some can also produce reasonable images.

There are also refractors that provide colour-corrected images, and these are called apochromats. These 'apo' or 'semi-apo' refractors often have Extra-low Dispersion (ED) glass in a doublet configuration or better still, a triplet arrangement that should eliminate colour-fringing. The process we are looking at here is not a replacement for using an apochromatic refractor to get the best star images, but it can transform images produced with an achromat.

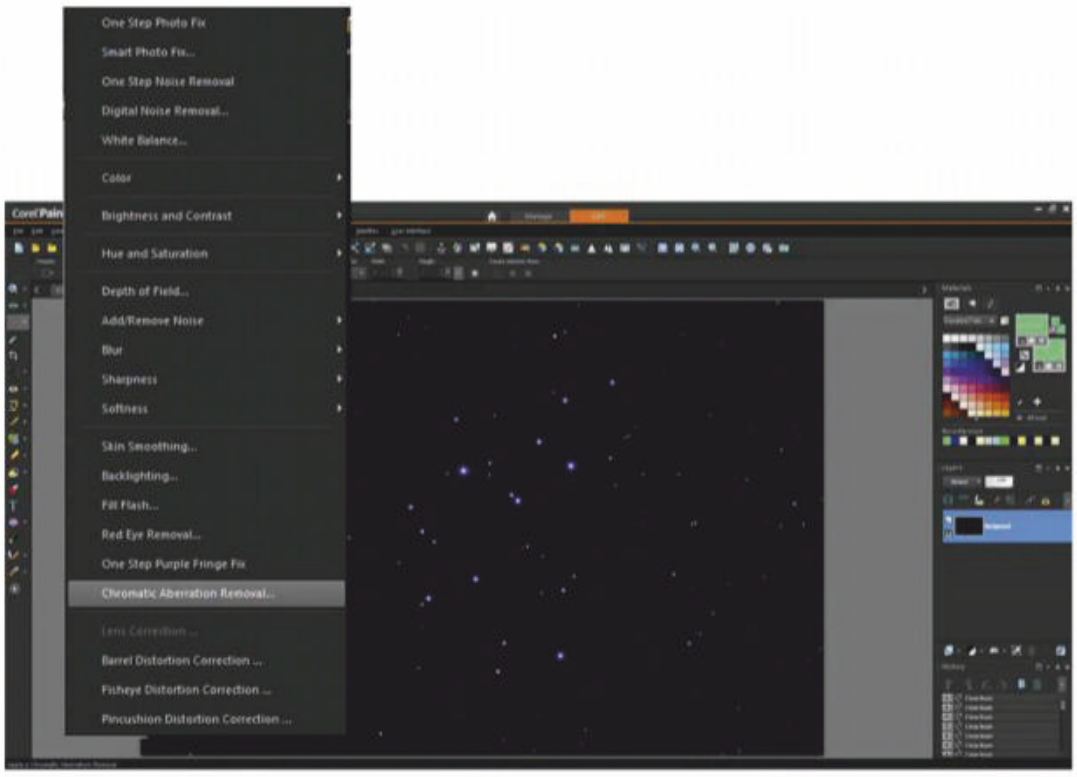
▲ Star cluster M39, captured with a 5-inch achromat, before (left) and after the colour fringes have been removed

Paul Money is an astronomy writer and broadcaster and is reviews editor for *BBC Sky at Night Magazine*

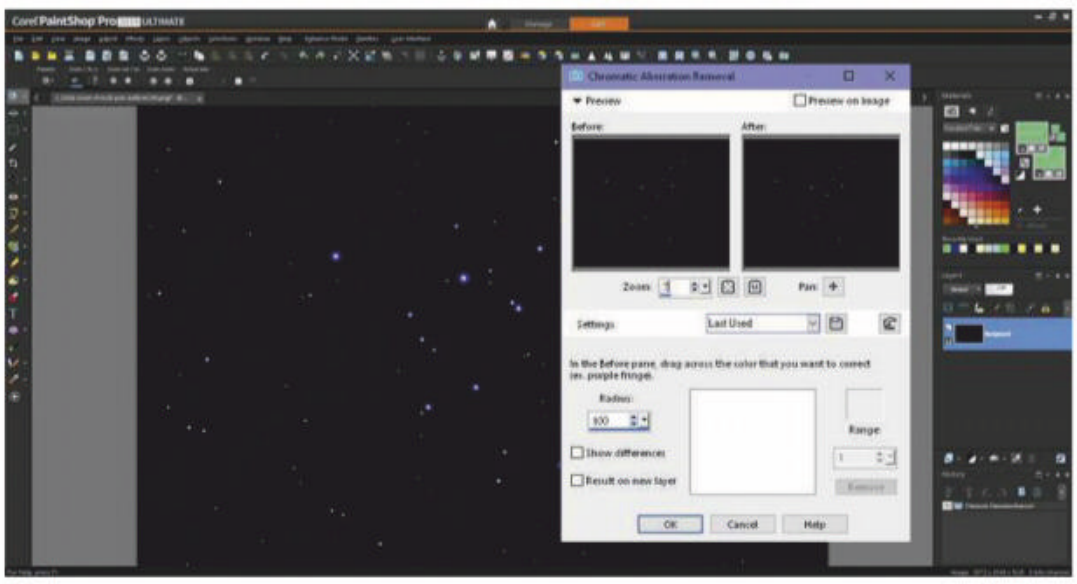
All in a night's work

Sometimes a little colour-fringing creeps in to images, be it from a change in the temperature or from perhaps not quite locking down the focuser, which allows a tiny amount of slippage. The resulting shots may have some chromatic aberration present and you might be tempted to abandon them, but before you do so it's worth trying out the 'Chromatic Aberration' tool found in most image-processing software. In our 'before and after' example of M39 (above), taken with a 5-inch achromatic telescope, we show how an image can be saved by using the popular PaintShop Pro 2019 software. It's well worth trying to salvage your image and save your hard night's work.

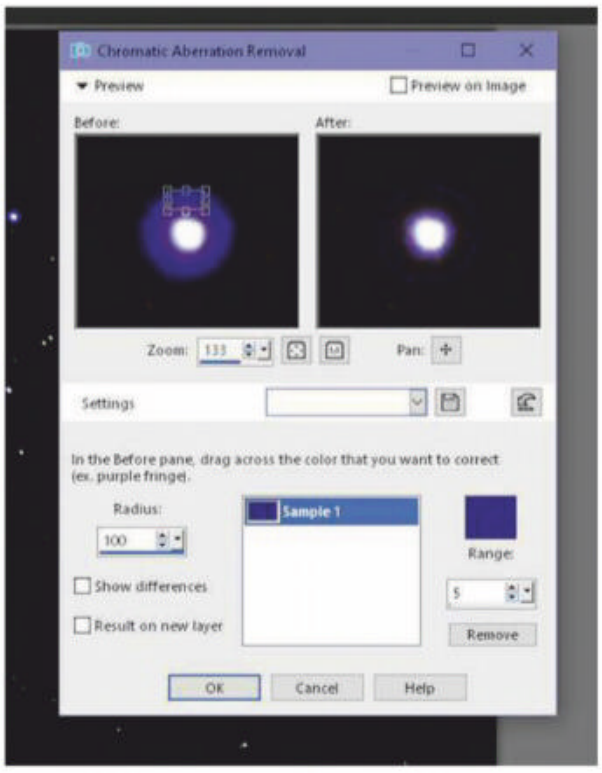
First, use your favourite stacking software to produce the primary image (see Stage 1 screenshot). Then load it into your image-processing software – in our case PaintShop Pro 2019. In our initial image you can see the blue fringing around the brightest stars and this is where the magic begins. Click on 'Adjust › Chromatic Aberration Removal' to bring up the 'Chromatic Aberration Removal' sub window (see Stage 2 screenshot). In the sub window we see a twin-screen view of part of the image. It is worth decreasing the magnification using the 'Zoom' tool to see most of the image as this allows you to select a suitable star for you to work on. Now use the 'Zoom' tool again to magnify a star that exhibits chromatic aberration particularly well, making sure you keep it



▲ **Stage 1: Image of star cluster M39 loaded into PaintShop Pro 2019 with the 'Chromatic Aberration Removal' sub menu selected**



▲ **Stage 2: The 'Chromatic Aberration Removal' tool window**



▲ **Stage 3 Taking a sample of the colour-fringing**

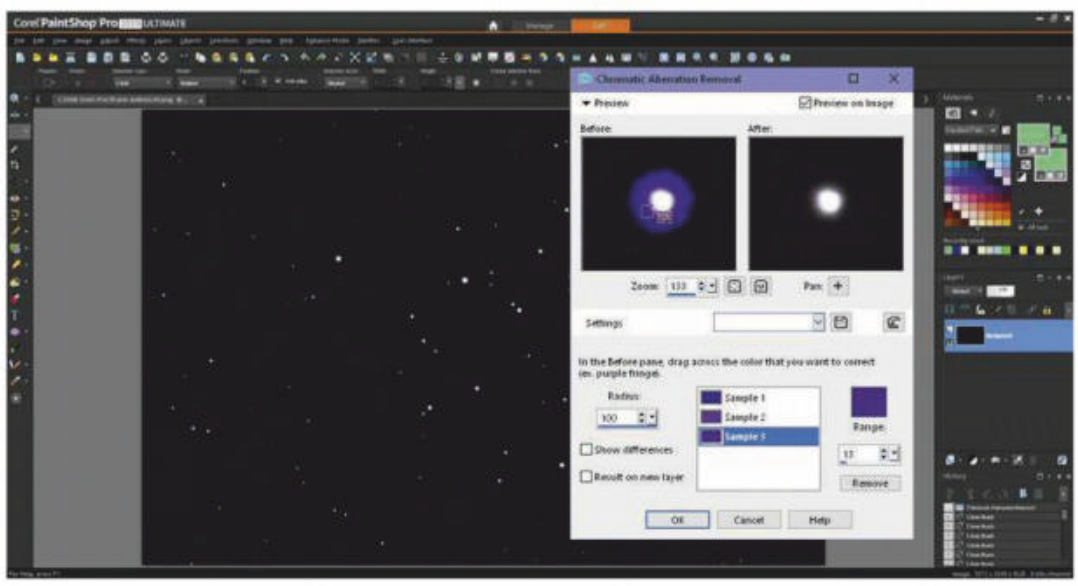
centred in the screen. If you wish, and have a reasonably powerful graphics processor, tick the 'Preview on Image' box at the top so you can see any changes you make on the main image, seen in this case to the left of the 'Chromatic Aberration Removal' window. At this stage, if this is the first time you have used it, the lower box will be blank until you make a selection box to sample the colour you wish to remove.

Now drag your cursor in the 'Before' window over the colour you wish to sample or select (see Stage 3 screenshot) – helpfully it even tells you to do this. Keep the 'Radius' setting at 100. The sampled colour will appear in the small right-hand box and it will also appear as 'Sample 1' in the main centre box. The selected box usually contains a range of the colours selected and you'll have better control if you keep the numerical value range around 5 or 6, otherwise too many hues of the colour are selected and you can end up with grey stars.

Once the selection is made, the right-hand window shows the effect on the star, and you can use this as a guide to see how much you want to change the colour around the star. As mentioned, if you use too large a range you can go overboard and ruin the stars making the image grey-scaled. Instead, we note the effect and can, if needed, make multiple selections (as shown in the Stage 4 screenshot). It is down to personal preference how much adjustment you make, but be careful as too many selections can make the star look bland. We prefer to leave a little colour around the star (as in Stage 3) which gives a more natural look. Bear in mind that there could also be nebulosity present in your image, and be careful not to affect that when you remove the chromatic aberration colour.

If you are happy with the result click on 'OK' to confirm the changes. Then you can either do a little more processing or save the image in whichever format you desire. This technique is well worth trying if it helps to save your preciously obtained images and hard work.

▼ **Stage 4: Making multiple selections of different parts of the colour-fringing**



3 QUICK TIPS

1. Using the 'Chromatic Aberration Removal' tool, ensure you zoom in close to see the colour-fringing around a bright star.

2. Try to select as small a colour range as possible when making your first selection.

3. If needed, adjust the range settings to around 5 or 6, as higher values may give grey stars.

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More **ONLINE**
A gallery containing these and more of your images

△ Horsehead and Flame Nebulae

Ethan Roberts, Shoeburyness, Essex, 20 December 2019 to 18 January 2020

Ethan says: "The Horsehead Nebula is one of my favourite winter objects to image. The weather had been quite bad this winter and meant it took about a month to capture the 20 hours of exposure time I had intended to acquire."

Equipment: Altair Hypercam 183M Pro Tec camera, Sky-Watcher Evostar 80ED apo refractor, Sky-Watcher NEQ6 mount
Exposure: Ha 10h, RGB 3.5h each
Software: DeepSkyStacker, SharpCap, Photoshop

Ethan's top tips: "Nebulae such as the Horsehead are very faint objects and require lots of exposure time to bring out the structure in good detail. For an emission nebula, I found it best to use narrowband filters such as hydrogen alpha to get a higher contrast. Then, RGB filters can be used to produce colour. The sub exposure length is also important as this determines how much light the camera will detect. Longer sub exposures will produce much sharper images and the faintest regions will be brought out better. To acquire these long sub exposures, a sturdy tracking mount and guiding are key."

The Moon ▷

Kevin Lyons, Webster, New York, 1 January 2020

Kevin says: "I captured this HDR image on the night of New Year's Day. It had been cloudy for weeks, so I was glad it cleared. The Moon was 26° above the horizon near mag. +4.4 star 30 Piscium, which can be seen left. It was occulted by the Moon 20 minutes later."

Equipment: Canon EOS 600D DSLR, Stellarvue Access 125mm refractor, Celestron CGEM mount **Exposure:** ISO 200, 12 exposures from 2.5" to 1/250" **Software:** EasyHDR, PaintShop Pro

◁ Welsh aurora

Bethan Cayford, Blaenavon, South Wales, October 2015

Bethan says: "I had to walk a good 30 minutes to the highest peak on the dune to get this view. It was slightly foggy and misty which cleared in patches, and I only had a five-minute window to get the shot."

Equipment: Samsung WB250F camera **Software:** GIMP

The Pleiades ▷

Stephen Tolley, Liskeard, Cornwall, 19 January 2020

Stephen says: "After what seemed like endless cloud in Cornwall, the weather finally gave me some amazing clear winter sky. This enabled me to get back to capturing the Pleaides, and try to get some good exposure time to bring out the nebulosity. I've seen some beautiful images of it and always wanted to capture it myself."

Equipment: Nikon D600 DSLR, Tamron 150–600mm lens, Celestron AVX mount **Exposure:** ISO 1,600, 11 x 300", 10 darks, 10 flats, 10 bias **Software:** APT, DeepSkyStacker, Photoshop

Monkey Head Nebula ▷

David Shaw, Consett, County Durham, 22 January 2020

David says: "As I was imaging from my back garden, under two LED street lights, I thought a narrowband target would be best, and the Monkey Head Nebula came to mind. I've shot this target before, but never with my QHY163m."

Equipment: QHY163m mono camera, Sky-Watcher Esprit 80ED apo triplet refractor, Sky-Watcher NEQ6 mount **Exposure:** 23 x 300" Ha, 23 x 300" OIII **Software:** PixInsight, APT, SharpCap

◁ Altair and Vega

Sérgio Conceição, Barrancos, Portugal, 3 August 2019

Sérgio says: "In this photo you can see the stars Altair and Vega and the Milky Way above the Castle of Noudar in Portugal. The castle is practically abandoned and many kilometres from the nearest lights, which makes for a very dark sky. I had to wait several hours for the Milky Way to be right in the centre of the image."

Equipment: Canon EOS R mirrorless camera **Exposure:** ISO 6,400, 15"

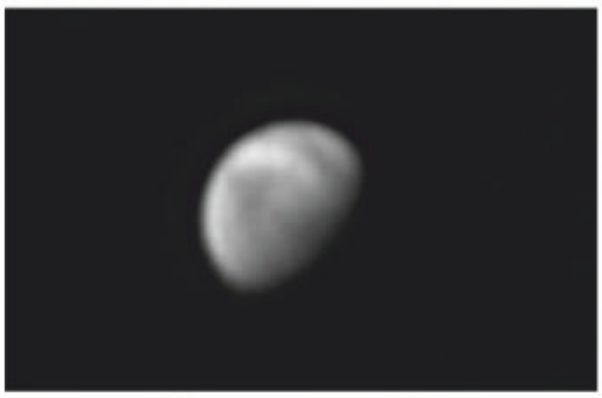
Bode's Galaxy, M81 ▷

Steve Fox, Camberley, Surrey, 22 January 2020

Steve says: "I took this from my light-polluted back garden near Camberley. I'd tried to capture M81 before with my unmodified DSLR without much success, so I used my new mono CMOS camera with narrowband filters to try to minimise the effect of light pollution. I'm still on a very steep learning curve, but I was extremely pleased with the difference the filters made to the final image."

Equipment: ZWO ASI 1600MM mono camera, Celestron Edge 9.25 SCT, Celestron CGX mount **Exposure:** 5 x 600" Ha, RGB 10 x 180" each **Software:** StarTools, GIMP

◁ Venus



Peter Presland, Biggleswade, Bedfordshire, 18 January 2020

Peter says: "Venus is a favourite target of mine. Despite its incredible brightness, it's not that easy to capture anything other than a featureless shape. But with a UV filter under good conditions you can capture cloud features. This image was taken during daylight hours, when Venus was at its highest point."

Equipment: ZWO ASI 290mm mono camera, Celestron C9.25 SCT, Sky-Watcher HEQ5 mount **Exposure:** 25,000 frames, best 10% stacked **Software:** FireCapture, AutoStakkert!, Photoshop

Rosette Nebula ▷

Bob Bowers, Haverhill, Suffolk, 20 January 2020

Bob says: "This was a good target for me, directly to the east over open fields, where there are no light issues. As it's quite a large target I wanted to see how the field of view would be with my new Celestron RASA 8 and the Atik Horizon camera – and I was very pleased with the result. I think the challenge is to get the star colours right to show the prominent yellow star."

Equipment: Atik Horizon one-shot colour camera, Celestron 8-inch Rowe-Ackermann Schmidt astrograph, Sky-Watcher AZ-EQ6 Pro mount **Exposure:** 89 x 120" lights, 30 x 60" darks, 30 bias, 50 flats **Software:** AstroPixelProcessor, Photoshop

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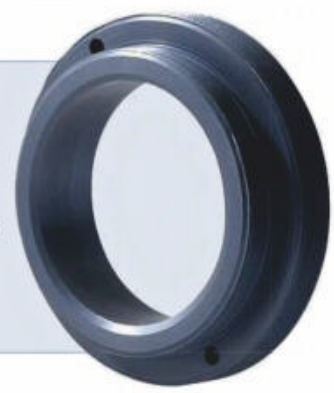
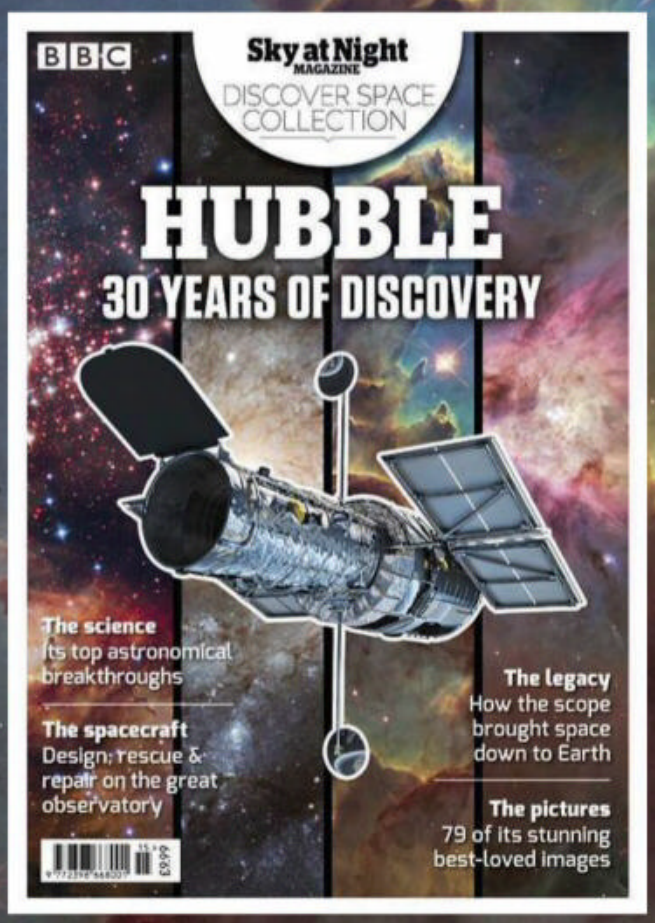
We've teamed up with Modern Astronomy to offer the winner of next month's Gallery a finder–guider adaptor, which connects T-thread guide cameras from ZWO, Orion and others to 9 x 50 standard finders from Sky-Watcher. The accessory comes with full instructions and support. www.modernastronomy.com • 020 8763 9953



SPECIAL EDITION



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The best in equipment, accessories and books each month

REVIEWS

Find out more about how we test equipment at
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Perfect pairing? We put the Altair 70 EDT-F refractor and Starlight Xpress Trius Pro 694 camera through their paces

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★☆ Very good
★★★☆☆ Good ★★☆☆☆ Average ★☆☆☆☆ Poor/avoid

PLUS: Books on Mars and Cecilia Payne-Gaposchkin's pioneering star discoveries, plus a roundup of gear

FIRST LIGHT

Starlight Xpress Trius Pro 694 mono CCD camera bundle

A reliable setup that has all you need to get imaging

WORDS: GARY PALMER

VITAL STATS

- **Price** £2,550
- **Camera** Starlight Xpress Trius Pro 694 mono
- **Sensor** EXview ICX694AL
- **Image format** 2,750 x 2,200 pixels
- **Camera size** 75 x 70mm
- **Filter wheel** Starlight Xpress mini filter wheel
- **Guide camera** SX Lodestar X2
- **Extras** Cables, power supply and capture software
- **Camera weight** 400g
- **Bundle combined weight** 1.2kg
- **Supplier** The Widescreen Centre
- **Tel** 01353 776199
- **www.** widescreen-centre.co.uk

Starlight Xpress has made some interesting improvements to its range of Trius cameras, which are called the Trius Pro series. In this review we are looking at the Trius Pro 694 mono bundle, which claims to contain everything you need to get you up and capturing images in one box.

The Trius Pro 694 bundle comes in a tough foam-lined case along with the Lodestar X2 off-axis guide camera and an SXMFW-1T mini filter wheel. Also included are all the cables, a power supply, capture software and drivers for the cameras and filter wheel. Looking at the camera on its own, the sensor is a medium-format, high-resolution EXview CCD chip, with 6,050,000 x 4.54µm square pixels in a 15.98mm diagonal array. The sensor window is fused silica glass, which is better at dealing with any air moisture. As well as a main high-speed USB2 port and three micro-USB ports for connecting accessories, there are two power ports to support the cooling and electronics, and a guide port is included in case it is needed in other applications.

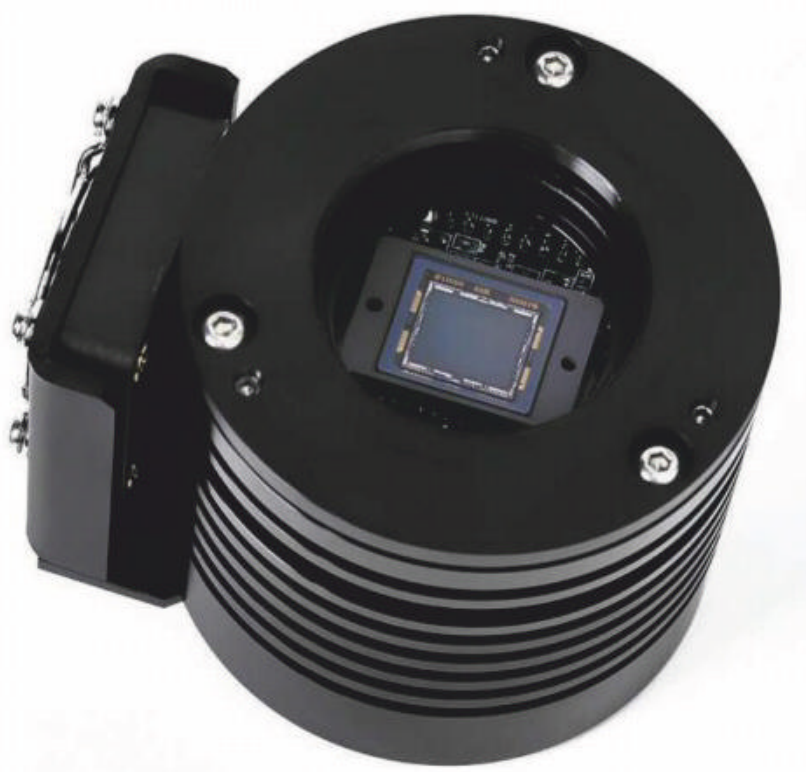
The Trius Pro 694 is a CCD-based camera and there is an ongoing debate about whether sensors of this type give the best image: some say that CCDs (charge-coupled devices) are being superseded by CMOS (complementary metal oxide semiconductor) sensor technology. Both types of camera produce good images, but many astrophotographers consider that CCDs still hold up a little higher in the quality of the images they produce. Some people argue that CCD cameras are outdated, but they are still being made by nearly all the major camera manufacturers, and in this case improved upon to give Pro versions.

First impressions

As soon as you open the case you'll be impressed by the attention given to the quality and design of the equipment; the camera is solid with a nice tough coat of paint and all the threads screw together nicely. Assembling the equipment is easy, as the guide camera and filter wheel are already assembled in the case, so all that needs to be done is to open the filter wheel, install ▸

Superior sensor

Sony's ICX694AL Exview CCD sensor has been around for a while, but now – coupled with the updated high-grade electronics in the camera's new Pro version – it gives even entry-level astronomers the ability to capture high-quality images. The specifications start with a medium-format sensor, with a pixel size of 4.54 x 4.54 microns and an image format of 2,750 x 2,200 pixels. This is housed in an Argon gas-filled chamber that is designed for zero maintenance, meaning there is no need to change any desiccant (drying agent) over the camera's life. The sensor has an improved lower noise reading (3 electrons), a reduction from the original Trius SX-694 (4–4.5 electrons), while the image download time is 2.5 seconds at full resolution, so pretty fast. The Grade 1 sensor rating means that it should contain no bad columns or dead pixels and no more than 50 hot pixels. We did indeed find this led to high-quality frames captured and less work to do in the final processing of the images.



ALL PICTURES: @THESHED/PHOTOSTUDIO

Delta T cooling

The camera has a Delta T cooling system which enables a temperature of –45°C and for every –5°C you halve the dark current. There are two fans built into the camera, one internal and the other external, cooling the heat-sinks built into the camera's casing.

USB hub

The Trius 694 pro has a high-speed USB2 hub built in with three mini-B USB ports where equipment such as the filter wheel and guide camera can be plugged in directly to the camera. This cuts down on cabling with just one main cable running back to a computer to control all the equipment.

Mini filter wheel

The mini filter wheel plugs into the back of the camera and has five slots for 1.25-inch filters. There's easy access for changing the filters with four large thumb screws on the case and the unit can be controlled from most types of capture software using the ASCOM system.

Off-axis guider

The prism for the off-axis guider is located in the top of the filter wheel. Focus on a guide star is easily attained by adjusting the two thumb screws under the guide camera. This design keeps the width small and helps with any back focus needed when using focal reducers.

FIRST LIGHT

Guide camera

A Lodestar X2 mono guide camera is included in the bundle and makes autoguiding a simple task. It has a Sony ICX829 sensor. There is a port for the guide cable from the mount and a USB2 socket that plugs into the main Trius camera.

KIT TO ADD

1. 1.25-inch CCD-imaging filter set

2. SkyX Pro software

3. Primalucelab's EAGLE 3 control unit

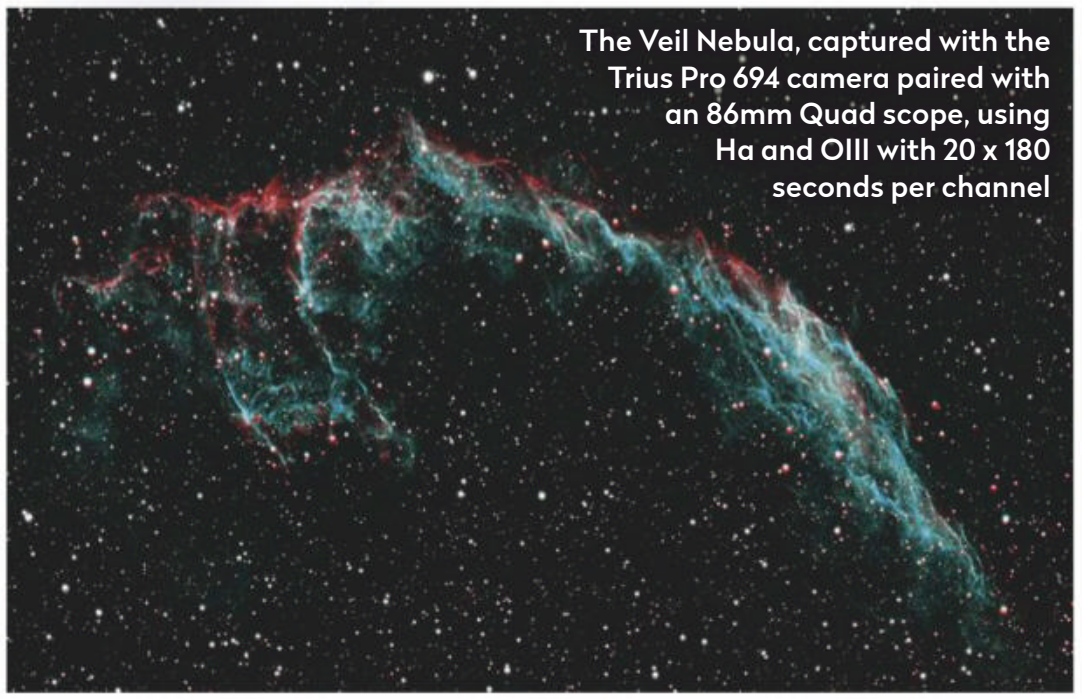
▸ the filters and then screw the camera on the back. The power supply has a splitter to plug in both ports on the camera, and the other cables for the guide camera and filter wheel are made to measure so there is nothing to catch on anything while it's being used.

Once the camera is installed on the scope it can be controlled by most software. For our review we used Sky X Pro, which has a camera add-on that controls cameras and ancillary equipment, and we used PHD2 for guiding the equipment. Once the main camera was focused, we set up the off-axis guider (OAG) and focused the guide camera. Care is needed to make sure the prism on the OAG is not too low as it will show up in any image captures. The guide camera is focused by sliding it up or down the OAG connecting shaft of the filter wheel, and it works well. In the PHD2 program, the guide camera works best if you capture a dark-frame set using PHD2's dark library wizard feature.

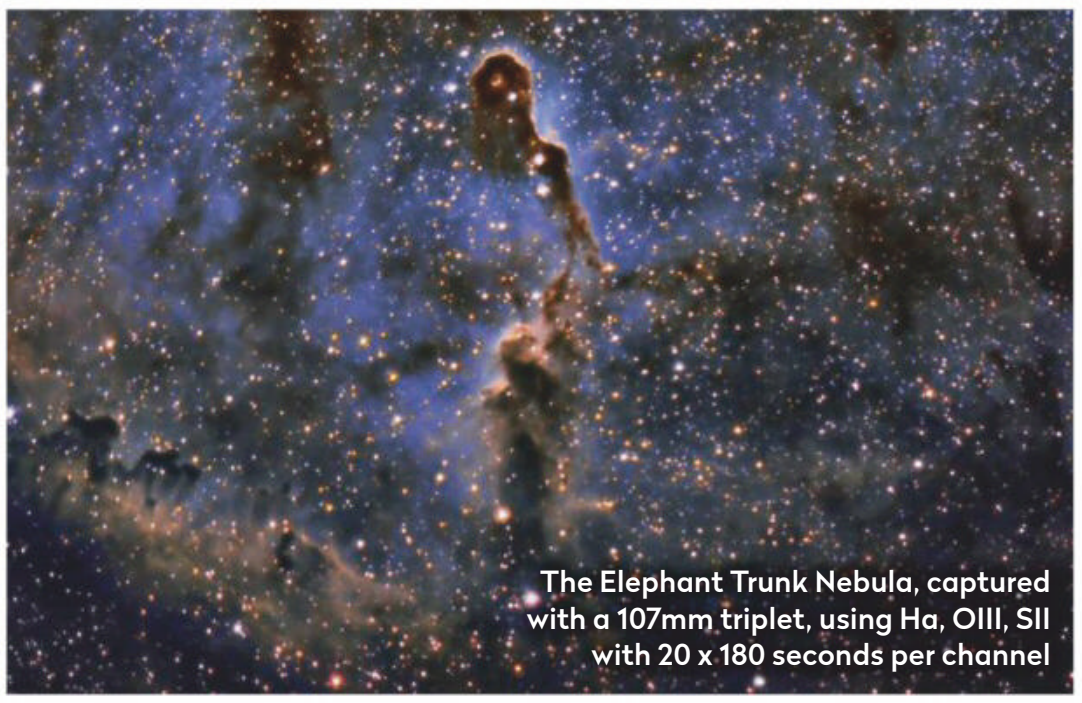
On target

Due to poor weather conditions over the review period the only clear spells were with a bright Moon, so we opted to use a narrow-band filter set. The Trius Pro 694 is listed in most capture software – we used Nebulosity 4 for our capture. Time was limited so we set the exposures for three minutes. Our first target was part of the Veil Nebula, while on another night we had a chance to capture some data on the Elephant's Trunk Nebula. Then we captured a full set of calibration frames for processing in PixInsight. After processing, the images proved to be satisfactory for their capture time, revealing lots of faint detail with next to no noise (unwanted artefacts) in the background.

The Trius Pro 694 bundle has something for everyone, while it is generally a deep-sky camera for imaging all types of those objects in the night sky, it can be used for imaging the Sun and Moon as well. The camera is Windows and Mac compatible and, with the included Starlight Live software, it allows you to stack images live as you capture them.



The Veil Nebula, captured with the Trius Pro 694 camera paired with an 86mm Quad scope, using Ha and OIII with 20 x 180 seconds per channel



The Elephant Trunk Nebula, captured with a 107mm triplet, using Ha, OIII, SII with 20 x 180 seconds per channel

VERDICT

Build & Design	★★★★★
Connectivity	★★★★½
Ease of use	★★★★★
Features	★★★★★
Imaging quality	★★★★★
OVERALL	★★★★½

@THESHED/PHOTOSTUDIO, GARY PALMER X 2

FIRST LIGHT

Altair 70EDT-F refractor and reducer/flattener

A highly portable triplet scope that delivers superbly at the eyepiece and on camera

WORDS: TIM JARDINE

VITAL STATS

- **Price** £699 + £100 for reducer /flattener
- **Optics** Triplet with Ohara S-FPL53 lens
- **Aperture** 70mm
- **Focal length** 420mm, f/6
- **Focuser** Rack and pinion with 1:10
- **Extras** Dovetail, clamp, accessory rail, T-rings, spacer
- **Weight** OTA 2kg, with reducer 2.6kg
- **Supplier** Altair Astro
- **Tel** 01263 731 505
- **www.** altairastro.com

ALL PICTURES: @THESHED/PHOTOSTUDIO

The Altair 70EDT-F is a travel-friendly refractor with premium optics, offering the choice between grab-and-go visual observing and astrophotography. Our review telescope came as a package, including a 0.8x reducer/flattener lens which corrects for inherent coma and takes the 70mm diamater lens from an f/16 to an f/4.8 and a working focal length of 335mm. This means that when it's combined with a DSLR or a dedicated astro camera, the 70EDT-F can present images with a field of view that's easily wide enough for a large nebula such as the Orion Nebula, M42, or extended star clusters like the Pleiades, M45.

Making an impression

The telescope has a stylish appearance, combining classic white with red anodized trimmings, and it has the look and feel of a well-made instrument. Although its construction is solid, the OTA weighs just over 2kg. Being around 30cm long with the dew shield retracted, the scope should easily fit into your hand luggage or a camera bag. Converting between the visual and photography modes is a simple matter of unscrewing the eyepiece clamp from the focuser drawtube, and then fitting the reducer/flattener directly to the drawtube, which eliminates any chance of introducing flex or tilt into the imaging train.

At first, we used the supplied T-ring to attach our full-frame DSLR to the flattener, which has a built-in helical adjustment for fine-tuning the spacing. This proved to be asking too much of the flattening lens, which is designed to work with APS-sized sensor DSLRs, so we swapped to a CCD camera with a smaller sensor and set about capturing images. The wide view on offer seemed perfect for the Horsehead Nebula region, and the nearby bright star Alnitak put the scope's optics through their paces. It was reassuring to see the images coming in without a harsh-coloured halo around Alnitak or reflection artefacts in the image. Although galaxies ▸

Triplet lens benefits

Often viewed as a complicated hobby, astrophotography can actually be quite simple using just a standard DSLR camera and a telescope. For best results though, the scope should be apochromatic, bringing all the colours of light to equal focus. To achieve this desired standard, the 70EDT-F uses three lenses, including one made of Ohara S-FPL53 ED glass, which is noted for having a refractive index close to that of natural fluorite – without fluorite's drawbacks. In practical terms, this means that you can use a one-shot colour camera, DSLR or CCD/CMOS, without filters, and the stars will appear tight, true to their natural colour, and without unwanted coloured haloes. To confirm the apochromatic nature of the 70EDT-F we took a few random colour images from our image datasets, separated them into individual red, green, and blue channels, and then compared star sizes at pixel level. On a good telescope, all channels produce similarly sized star images, and the images we checked from the 70EDT-F were excellent in this regard.

Dovetail bar, clamps and accessory rail

The clamps on the 70EDT-F are beautifully machined to reduce weight and add functionality. A matching, short Vixen-style dovetail bar is supplied, along with an accessory rail and guide-scope clamp with incorporated bubble levels. The accessory rail doubles as a useful carrying handle while offering multiple attachment possibilities.

Visual mode

The matching eyepiece clamp attaches easily to the focuser, and accepts 2-inch and 1.25-inch nosepieces, holding them firmly in place with three thumbscrews on the compression ring. An extra, single-locking thumbscrew allows the assembly to rotate, making it easy to get the eyepiece into position as you switch from target to target.

Focuser

A rack and pinion design, with 1:10 fine-adjustment gearing and dual-locking knobs, the focuser operates smoothly and has incremental drawtube markings for repeatable settings. Our review model handled the combined weight of our camera, off-axis guider and the hefty reducer/flattener lens effortlessly, with no slop or slippage issues.

Dew shield

The business end of the telescope is protected from stray light and excess dew by a sliding shield, which extends 60mm. This is snug fitting and glides smoothly with no play in it. It's locked in place with neat, concealed Allen bolts, although the required Allen key is not included.

FIRST LIGHT

KIT TO ADD

1. Altair 2-inch magnetic filter holder

2. Altair 2-inch TriBand filter

3. Altair Hypercam 183C camera

▸ are presented as small objects at this focal length, our images of the Leo Triplet and The Whale and Hockey Stick galaxies demonstrated that the Altair 70EDT-F produces good, contrast-rich pictures with accurate star colours. The beauty of a refractor is that they offer hassle-free imaging, and this one was no exception, just an occasional tweak of focus was required, in line with temperature changes.

Take a sky tour

You can get great pleasure from taking a tour of the skies with a good small refractor. After removing the flattener/reducer lens, and adding our own diagonal and a 13mm eyepiece, we enjoyed an observing session at 32x magnification. Starting with a quarter-illuminated Moon, the contrast-rich views allowed crisp observations of the terminator, the craters of Mare Crisium, and the ridges, mounds and hollows within Mare Fecunditatis, as well as some details lit dimly by earthshine. With a 4.5mm eyepiece, working at 93x, the details were tight and clear. We did notice the slightest hint of a green and yellow fringe on the brightest edge of the Moon, but it was nowhere near enough to distract from the enjoyment of the view.

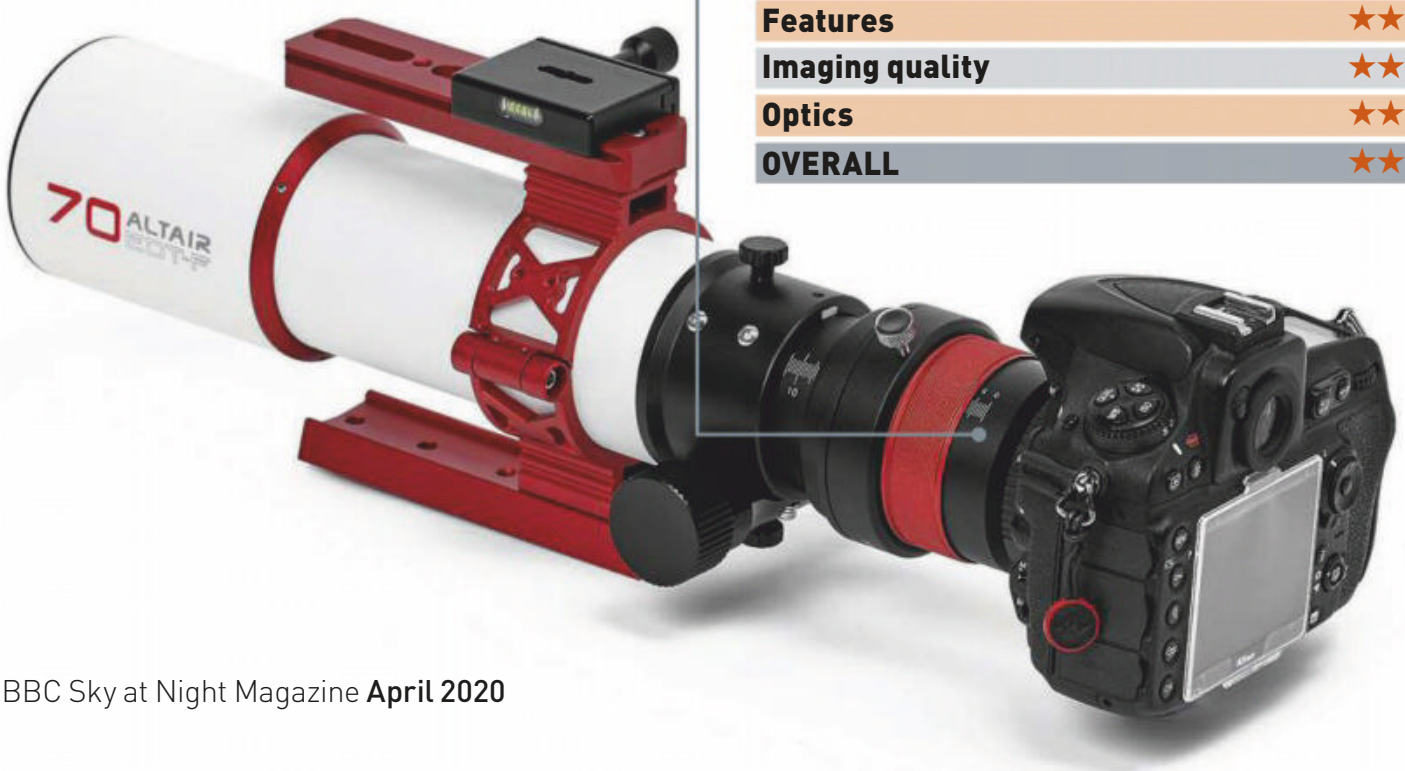
Turning to the Pleiades, M45, at 33x, the main cluster stars were round and crisp while, as expected, those nearer the edges of the view tailed off a bit due to coma. The brightest parts of the Orion Nebula, M42, presented a glorious sight, snuggled around the Trapezium area. The view was clear and sharp with a decent amount of nebulosity visible in our suburban skies, no doubt assisted by the high-transmission coatings on the lenses. While navigating Orion we also took a peek at Betelgeuse, and it was good to see it presented with strong orange colouring. Although triplet refractors may be viewed as a luxury for observing, the good, true colour views present a strong argument in their favour, and the ability to travel easily to dark clear skies with the Altair 70EDT-F makes it even more attractive as an investment.

Overall, we found that the Altair 70 EDT-F with the reducer/flattener lens provides all round performance and great results from an eyepiece or a camera.

▲ **The Orion Nebula, M42, as captured by the Altair 70 EDT-F paired with an Atik 460EX camera, using 3 hours 42 minutes of mixed-length exposures**

Photography mode

The chunky flattener/reducer lens incorporates a rotating ring for precise framing of your image. It attaches to the drawtube with a dedicated adaptor, while the rear of the unit has a standard, male, M48 thread, to which spacers can be added to achieve the correct distance to the camera for optimum coma reduction.



VERDICT

Build & Design	★★★★★
Ease of Use	★★★★★
Features	★★★★½
Imaging quality	★★★★½
Optics	★★★★½
OVERALL	★★★★½

@THESHED/PHOTOSTUDIO, TIM JARDINE

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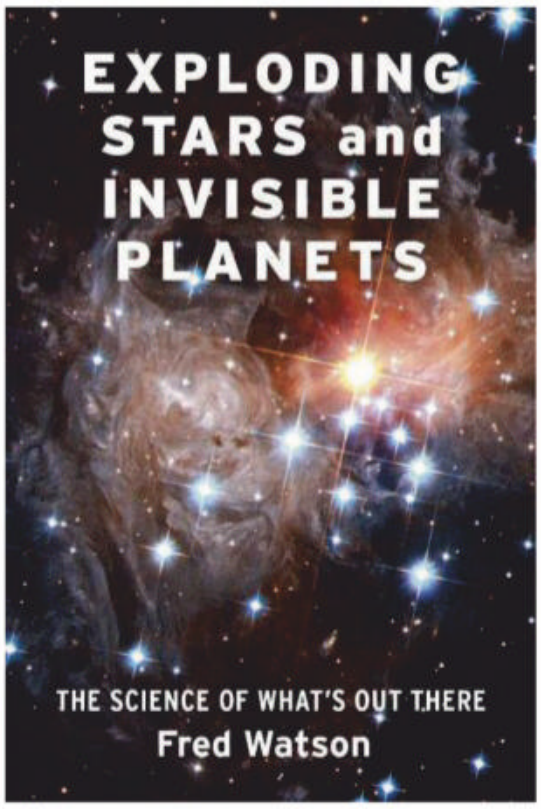


Exploding Stars and Invisible Planets: The Science of What's Out There

Fred Watson
Columbia University Press
£22 ● HB

Astronomy is often said to be the oldest science and yet, for all our space exploration, we still have more questions than answers. Was there ever life on Mars? Is there a ninth planet hiding on the outskirts of our Solar System? How did the first stars form? Why can't we detect the 95 per cent of the Universe that is 'dark'? Are we alone?

For people like Fred Watson – official Astronomer-at-Large for the Australian government – these enduring and evolving mysteries are the spice to a long career in astronomy and astronomy engagement, and this highly entertaining book is Watson's love letter to the cosmos, complete with hand-drawn sketches and iconic imagery. It is a whistle-stop tour of the latest developments in space exploration, from Earth's local space neighbourhood to supermassive black holes and the very birth of the Universe.

The chapters whiz along with pithy prose and just the right level of detail to stoke the curiosity without being overwhelming. We start at Earth, but even something as commonplace as twilight is given a new romance as we are introduced to the science behind elusive 'crepuscular rays' and the 'Belt of Venus'. The next few chapters remain in Earth orbit, exploring meteors, satellites and the Moon, before launching off to the mysteries of our Solar System and on to the Universe at large.

Watson tackles nuances in stellar formation theories and planetary protection in an engaging and accessible way, without ever losing the depth of intelligence that sparkles through. Even old hands in astronomy will come away with a few nuggets and lightbulb moments, where familiar topics take on a new perspective.

▲ **After an Earth-bound start with crepuscular rays the book soon takes off**

This is a bang-up-to-date survey of the cosmos, the flip-side being that it could soon show its age. Speculations about future lunar and Martian exploration, and the politics of private companies such as SpaceX and Virgin Galactic may well pass their prime in a quickly evolving space landscape. But that is all the more reason to read this book soon, bringing as it does the sheer wonder of space to life with quirky stories, endless passion and a great deal of fun. ★★★★★

***Tamela Maciel** is the space communications manager at the National Space Centre in Leicester*

STOCKTREK IMAGES, INC./ALAMY STOCK PHOTO

Interview with the author Fred Watson

How did you first get interested in astronomy?

I grew up in postwar Britain and went to school in the 1950s and '60s. Space science and astronomy were the hot topics and I was just as star-struck as everyone else. But I remained star-struck for the rest of my life. I worked at both Royal Observatories in the UK before coming to Australia on deployment to the UK Schmidt Telescope. For 20 years, I was Astronomer-in-Charge of the Australian Astronomical Observatory, managing its scientific output and helping to protect its night skies from light pollution. When the observatory transferred to the university sector I was appointed the nation's first Astronomer-at-Large. It's an outreach and advocacy role, and it's my dream job. It lets me talk astronomy, space and STEM to anyone who'll listen.

How is Australian astronomy doing?

It's in very good shape. In 2017 we entered a 10-year partnership with the European Southern Observatory to give Australian astronomers access to the world's best optical telescopes in northern Chile. And Australia [along with South Africa] will host the Square Kilometre Array, the world's biggest radio telescope, when it's completed later this decade.

What are the big challenges ahead?

Light pollution and radio frequency interference remain threats, and the roll-out of huge satellite constellations is hardly helpful. But a 'good' challenge is that today's technology has resulted in astronomers being swamped by data, with fantastic discovery potential.

***Fred Watson** is an author and Australian Astronomer-at-Large*

Mars: Explore the Mysteries of the Red Planet

Shauna Edson, Giles Sparrow, Mark Ruffle
DK
£9.99 ● HB

Has there ever been life on Mars? How long is a day there and what would be the best material to build homes on the Red Planet? These are some of the questions answered in this book.

Astronomy educators Giles Sparrow and Shauna Edson, and illustrator Mark Ruffle have created a fascinating guide to the Red Planet for both children and curious adults. It explores the history of Mars, while highlighting space technologies that reveal its present and give an insight into its future.

"Any building on Mars will need to be airtight, to protect the people inside from the thin, toxic Martian air. They will also need to protect against extreme temperatures and radiation on Mars," the authors write. Although no human has been to the Red Planet yet, *Mars* explains what visitors might be able to see, hear, feel and even smell and taste there. For example, where does the smell of rotten eggs and metal come from?

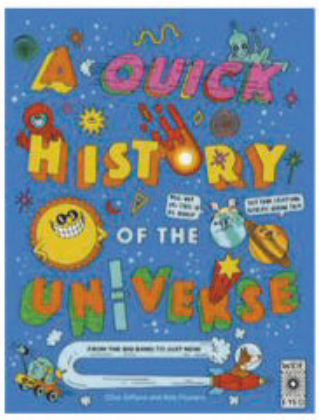
The book is illustrated with incredible pictures captured by NASA's Mars Reconnaissance Orbiter, and current space missions to the planet play an important role throughout. But the book's unique angle is its focus on humans: those who are behind the robotic missions sent to Mars and those who will visit the planet in the future. There is even a checklist of skills for budding astronauts to find out the abilities they'll need to become a Martian! This is an inspiring, educational and entertaining way to discover our neighbouring planet. ★★★★★

***Sandra Kropa** is a science journalist*

A Quick History of the Universe

Clive Gifford, Rob Flowers
Wide Eyed
£9.99 ● PB

GREAT FOR KIDS



There are many books claiming to give a brief history of the Universe, but there can be few as concise as *A Quick History of the Universe*, at least in terms of words.

Aimed at somewhat younger readers than most cosmology books, perhaps aged 10 or so, there is relatively little jargon that isn't explained – though some familiarity with concepts such as matter being made of particles would help. More technical terms are defined (and there's a brief glossary), often emphasised with interesting typefaces (again, appealing to younger readers).

But that doesn't mean it shies away from content. Beginning at, well, the beginning, the book whizzes through the usual fare: from the Big Bang and creation of the elements to the formation and evolution of galaxies, stars and planets, the evolution of life, and finally the end.

On the way it pauses to consider brown dwarfs, hairy stars, superclusters and photosynthesis. There's a nice compressed history of the Universe (scaling down to one year) and a couple of pages on how we know what we know.

Rob Flowers's plentiful illustrations are very colourful and eye-catching, and complement the text throughout. The book's gentle humour – in both text and images – isn't too distracting and will appeal to kids (I chuckled at points, but maybe that says more about me).

For readers who then want to find out more, there are suggestions of places to visit, books and magazines to read, and websites to check out. There's even a quick quiz. ★★★★★

***Dr Chris North** is Odgen science lecturer and STFC public engagement fellow at Cardiff University*

What Stars Are Made Of: The Life of Cecilia Payne-Gaposchkin

Donovan Moore
Harvard University Press
£23.95 ● HB

Before Cecilia Payne-Gaposchkin, it was generally assumed that stars were made of much the same material as Earth. As this book shows, Payne changed all that, discovering and proving that the most abundant elements in stars were helium and hydrogen.

Incomprehensibly, it is still rare to find commercial history of science books focusing on women's lives, and so this book stands out as one such rare example. Payne comes across as a fascinating woman, navigating the various gender-based obstacles in her way to build a life and career in a new subject (astrophysics) in a new country.

The book follows her life from early childhood, via her training at Cambridge to her successful career in America. The excellent, evocative foreword by Jocelyn Bell Burnell, which compares her own and contemporary female scientists' experience with that of Payne, is likely to have many women nodding in recognition.

Moore's book is very readable, broken down into short, engaging chapters that take us chronologically through Payne's life. There are interesting descriptions of her working relationships with various better-known male scientists. Her voice comes through too, as does her excitement, energy and enthusiasm.

While the archival evidence is fascinating, the book does lack the broader perspective offered by the last 30 years of scholarship on women in science. Without this perspective, Payne ends up being frequently praised as "not like other girls", suggesting a rather low opinion of other women. Beyond this omission, I found this an entertaining, engaging and informative read. ★★★★☆

***Emily Winterburn** is author of* The Quiet Revolution of Caroline Herschel: The Lost Heroine of Astronomy

Elizabeth Pearson rounds up the latest astronomical accessories

GEAR

1 Altair Tri-Pier

Price £325 • **Supplier** Harrison Telescope
Tel 01322 403407 • **www.harrisontelescopes.co.uk**

Compact and portable, this pier provides a stable base for astronomy on the go. The swivel feet of the tripod ensure even surface contact, while the Tri-Pier weighs 8.9kg and comes with a padded carry bag.

2 PrimaLuceLab 2-inch robotic micro focuser

Price £510 • **Supplier** Astroshop.eu
Tel 020 3868 8042 • **www.astroshop.eu**

Achieve extreme precision control of your focusing with the help of this robotic device. The focuser has a resolution of 0.04 microns per step and can be controlled via any Windows computer.

3 ADVANCED OVNI-M night vision eyepiece

Price £5,449 • **Supplier** Astrograph
Tel 0843 330 4988 • **http://astrograph.net**

Specifically designed for astronomy, this eyepiece uses the same phosphor tubes found in night vision goggles to amplify the dim light of deep-sky objects. Can be used alone and comes with an adaptor to fit 1.25- and 2-inch filters.

4 Thermal socks

Price £9.99 • **Supplier** Heat Holders
www.heatholders.co.uk

Keep your feet comfortable and snug during a cold observing session. These socks are crafted from specially brushed long fibres making them seven times warmer than conventional cotton socks.

5 Animals in the Sky

Price £8.95 • **Supplier** Phaidon
Tel 020 7843 1000 • **http://uk.phaidon.com**

Help the little astronomer in your life learn the constellations. Each page of this book shows a star pattern alongside a clue of what it might depict, then unfolds to show which animal the stars are said to make.

6 LEGO International Space Station

Price £64.99 • **Supplier** LEGO
http://lego.com

Build your own International Space Station with this 864-piece LEGO set. The set has posable solar panels and comes with a mini Space shuttle, three cargo spacecraft and two astronaut microfigures.

Elizabeth Pearson interviews Jerry Woodfill

Q&A WITH AN APOLLO ENGINEER

During the rescue of Apollo 13, thousands of people helped to bring the crew home. We talk to one of them who was in Houston at the time of the accident

How were you involved with Apollo 13?
I was the spacecraft alarm system engineer for the Apollo Program, the person responsible for the design and operation of the Apollo spacecraft alarm system and setting the criteria that would ring an alarm the astronauts could respond to. During the missions, I was in the mission evaluation room. The room contained 70 engineers – not just NASA engineers but contractors too – with an intimate knowledge about every system; how it's designed, how it's tested, and its performance parameters.

▲ **Action stations: Jerry Woodfill (left) is on hand for any hardware queries in the mission evaluation room during the Apollo 11 mission**

What happened during the accident?
It was 9:08pm (local time in Houston) on 13 April 1970. I had my headset on. I was watching the consoles, the same display the flight controllers were seeing, and then all at once, I watched that console flicker, like an old TV set. It recovered itself, but then I heard in my headset, "Houston, we've had a problem".

What was the problem?
The alarm that came on was a main B bus undervolt – one of the two buses that carry power around the spacecraft had a low voltage. That got my attention. When I heard the call, I thought, 'Oh no, it's my system, I've caused the problem here!' There were five or six different alarm lights turned on. I thought it couldn't really be that bad, but then [Apollo 13 commander] Jim Lovell said, "We see something venting". That's when I knew we had a real problem and it wasn't my system: we'd have to work to get those guys and rescue them.

What was it like at Houston during that time?
Those first few hours were crucial, because decisions were happening very quickly. [Flight director] Gene Kranz was beautiful, telling everyone, "Let's not be guessing anything." People were talking over one another. It was a big job and lives were in the balance so you can understand there were a lot of concerns and people were trying to understand what was really going on. It was a little confusing, but most things had previously been done in simulations. That kept things organised, since most things had been practised. There was usually a backup procedure, a plan. The exceptions were solving the carbon dioxide-filter problem and charging the depleted entry batteries. The mission evaluation room team solved those problems.

Jerry Woodfill was the spacecraft alarm system engineer during the Apollo Program. Still working at NASA after 54 years, he is one of the agency's longest serving employees

What was it like when you realised they were successful?
When I saw those three parachutes deploy, it brought tears to my eyes. Compare that to 1967 when Apollo 1 caught fire, and we lost three guys on the launch pad, when there was such sorrow. This time it was just wonderful to know that our team was able to save the crew, that we all worked together to save those three guys' lives. We were beyond just being grateful; there was a satisfaction and a pride in the knowledge that everything we had done was because we'd taken the time to engineer things correctly.

How has the Apollo 13 rescue been remembered?
I submit to you that everybody equals the rescue of Apollo 13 to putting a man on the Moon. It was a wonderful thing. There's never been a real, exciting movie made about Apollo 11, but that movie about Apollo 13 is still being watched over and over again. When men's lives are threatened, and you see people work together to rescue them, it's a story that really will never be forgotten. It's as important as the first person walking on the Moon.

How accurate was the movie *Apollo 13*?
They did a real good job of showing what was going on in the mission evaluation room. That part where they make the square filters fit into the round holes on the lunar lander, that was the mission evaluation room guys doing that, not Mission Control or the astronauts. That's engineers who knew what things were on board and how to jury-rig a system to make the filters fit. The movie also does a real good job of capturing Gene Kranz and [flight controller] Sy Liebergot, and all the guys who helped bring those men back alive.

JERRY WOODFILL/NASA

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

The Southern Cross returns to the autumn skies, alongside the peak of the Pi Puppids

When to use this chart

1 Apr at 24:00 AEDT (13:00 UT)
15 Apr at 23:00 AEDT (12:00 UT)
30 Apr at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

APRIL HIGHLIGHTS

This month a meteor shower is ideal for Southern Hemisphere observers. Conditions for the Pi Puppids are perfect in 2020 with maximum expected around the 23rd, right on new Moon. They are visible from around 15 to 28 April. Although the Pi Puppid rates are low (typically 3 to 5 per hour) with the peak varying every year (40 per hour in 1977), they're worth the wait, being bright with trains and occasional fireballs. It's best to observe in the evening before the radiant in Puppis gets low.

STARS AND CONSTELLATIONS

A welcome feature of autumn evenings is the Southern Cross. It may come as a surprise that the stars making up Crux were well-known to the mid-latitude Northern Hemisphere ancients who created the constellations. At that time, precession had the Cross and Centaurus sitting on their southern horizon. Ptolemy catalogued Crux's stars as part of the Centaur's hind legs. It's interesting that such a prominent star as Alpha Crucis ended up with the modern (boring) name Acrux.

THE PLANETS

Venus dominates the early western evening sky. It can be seen crossing the edge of the Pleiades on the 3rd and 4th. The planetary action continues with Jupiter rising just before midnight, to be followed around 30 minutes later by Saturn.

During April Mars is close to the ringed world, arriving at 01:00. All three planets are best observed in the mid-morning sky. Early in the month, Mercury is well-placed to see in the eastern dawn sky, dropping into the solar glare in late April.

DEEP-SKY OBJECTS

Crux might be the smallest constellation, but it holds its own in the deep-sky stakes. The top star of the cross is the brilliant triple, Gamma Crucis or Gacrux (RA 12h 31.2m, dec. –57° 07'). Its orange primary (mag. +1.6) has two companions, an obvious white component and another at mag. +6.4 and +9.2 respectively. Arranged in a near equilateral triangle shape, with sides of approximately 2 arcminutes, they look best at low power.

NGC 4103 (RA 12h 6.7m, dec. –61° 15') is an open star cluster. Located 2° west-southwest of bright Epsilon Crucis, this 7th magnitude cluster consists of around 70 stars ranging from 9th to around 13th magnitude, well scattered across a 5' circle, forming straight and curved lines. The edge merges into the surrounding rich star-field and a handful of brighter stars surrounding the cluster makes it a real looker.

Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
URSA MAJOR
M51
M106
BOÖTES
CANES VENATICI
M63
M94
Cor Caroli
Kite
LYNX
LEO MINOR
M3
COMA BERENICES
Arcturus
M64
Denebola
LEO
Sickle
30th
3rd
M44
Ecliptic
Regulus
M105
M95
M96
M86
M87
M84
6th
VIRGO
CANCER
CANIS MINOR
ORION
Procyon
M5
Celestial Equator
Spica
M104
CRATER
HYDRA
Alphard
9th
LIBRA
CORVUS
Ghost of Jupiter
M48
MONOCEROS
Winter Triangle
M83
CENTAURUS
Cen A
M4
Antares
LUPUS
ANTLIA
PYXIS
M93
M47
VELA
CRUX
Hadar
Rigel Kent
Jewel Box
Coal Sack
NGC 4103
Actux
Sirius
M41
NORMA
CIRCINUS
MUSCA
False Cross
PUPPIS
CANIS MAJOR
Pi Puppids
Peak 23 April
ARA
TRIANGULUM AUSTRALE
CHAMAELEON
CARINA
SCOPIUM
APUS
NGC 3195
VOLANS
Canopus
COLUMBA
South Celestial Pole
MENSA
PICTOR
Tarantula Neb
LMC
PAVO
OCTANS
SMC
DORADO
47 Tuc
HYDRUS
RETICULUM
INDUS
TUCANA